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MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

VOLUME XXI

CONTAINING PAPERS SUBMITTED AT THE ANNUAL MEETING IN 1935

PAPERS

OF THE

MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS

EUGENE S. McCARTNEY
UNIVERSITY OF MICHIGAN

ALFRED H. STOCKARD
UNIVERSITY OF MICHIGAN

VOLUME XXI

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— SENECA, *Naturales Quaestiones*

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THE USE OF BEVELED DISCOIDALS IN NORTHERN GEORGIA

WILLIAM B. COLBURN

THIS paper has to do with a method of bowling, practiced by the Cherokee Indians, in which the beveled discoidal had a very definite use previously unknown to, or at least unrecorded by, any anthropologist or historian.

During the first three months of 1932 I directed the partial excavation of a mound located on J. J. Greenwood's farm about one half of a mile northeast of Dillard in Georgia and one quarter of a mile east of the main highway between Franklin, North Carolina, and Clayton, Georgia. The mound was oval, roughly one hundred and thirty feet long by one hundred feet wide, with its long axis running nearly due north and south (Fig. 1).

My preparatory work, after clearing the mound of the brambles and cornstalks (see Pl. I, Fig. 1), was to choose, arbitrarily, a center of the mound, which I marked by a post, and from that point, with the efficient aid of Mr. Milky, a government surveyor from Franklin, to survey the mound and its immediate surroundings. I had learned from the owner that for at least three generations the plowing done each year over the mound had been from north to south, and so I decided to include in my excavation the fifty-foot strip lying due south of the mound proper, in order to recover any sherds or artifacts dragged down by the plows. I therefore enclosed the mound in a rectangle one hundred and ninety feet long by one hundred and thirty-five wide, with posts driven into the ground at five-foot intervals, and with the northern and eastern lines only ten feet distant from the mound, as indicated in the floor plan (Fig. 1).

A preparatory trench five feet wide was then dug along the southern side of the rectangle, to a depth of two or three inches below the undisturbed earth; at the eastern end of the trench the required depth proved to be three feet and at the western end slightly over five feet. Owing to the absence of sherds and charcoal in either

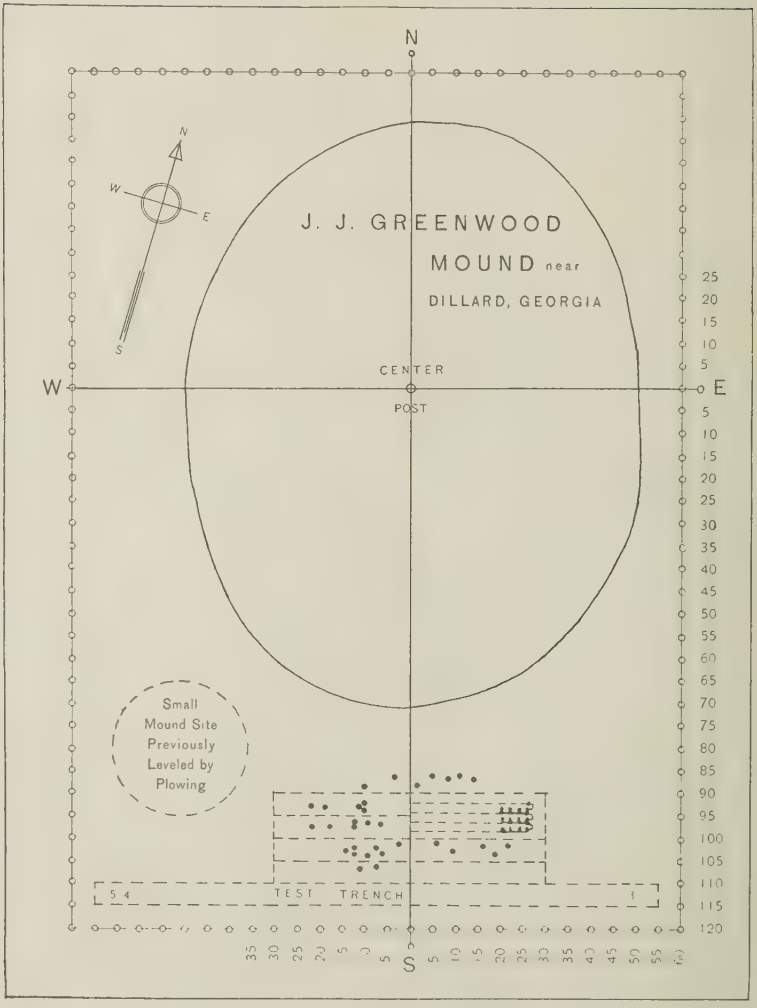


FIG. 1. Floor plan of the J. J. Greenwood mound, near Dillard, Georgia

end of this test trench, it was decided to continue the excavation toward the mound on a sixty-foot front, thirty feet to either side of the center or zero line. During the excavation of the first two five-foot strips along this sixty-foot front fourteen discoidals were uncovered, two in the first and twelve in the second. Some are illustrated in Plate I, Figure 3.

When the south 100-foot profile wall had been shaved back a distance of two feet, a line of field rocks was encountered between east 20 and 30 on profile line south 98. At the same level, an average of three feet below the surface, a stratum of hard-baked clay extended about twenty feet to the west from the western end of the row of field stones. As the work of uncovering these features progressed, we discovered that the stones were arranged in three definite similar groups or patterns of four open squares, three with their open sides at right angles to the clay runways or alleys, and a smaller one directly facing the left-hand side of these runways.

The baked-clay floors were perfectly level and about two feet six inches in width; each strip uncovered as we worked north was about three inches higher than the one south of it. Opposite the openings to the three large squares rough-hewn or split sections of tree trunks had been embedded in the earth, evidently to hold in place the row of field rocks forming the back of the square of the next alley above, as well as serving as fenders. These extended approximately two feet to the west of the field rocks, and each terminated at a large rock forming the left-hand upper cornerstone of the small square in each alley. All these features are portrayed in Figure 2.

During the excavation of the remainder of the two five-foot strips in which these alleys were uncovered eleven more discoidals were found, and later seven others were unearthed in the five-foot strip to the north. In all, thirty-two discoidals were found in the immediate vicinity of these alleys, all lying upon the original humus line; seventeen, or more than half of them, were of the beveled type which, when bowled or rolled with the larger diameter to the left, would, upon loss of momentum, naturally curve to the right in the same manner in which the lawn-bowling ball of our day curves to whichever side is weighted. The Cherokee Indians made these discoidals with a beveled edge so that they might be curved into the hollow squares opening at right angles to these alleys. This form

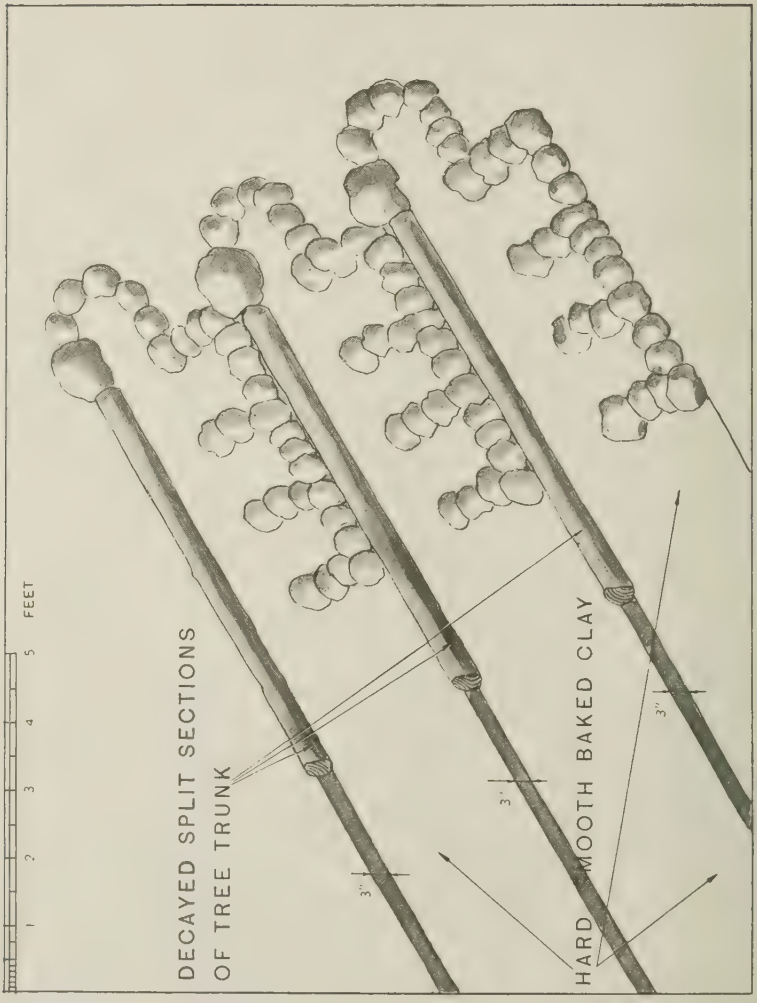


Fig. 2. The eastern end of the bowling alleys

of bowling must have been known to and been practiced by the whole Cherokee nation, because discoidals of this type have been found commonly throughout their former domain.

During the last ten years we have obtained from Cherokee territory for the Cherokee collection of Burnham S. Colburn at Biltmore Forest, North Carolina, over two hundred discoidals of all types. These we have classified into four main divisions: first, barrel; second, doubly concave; third, beveled; and fourth, the straight or common variety. The first of these, the barrel type, named from its resemblance to a barrel, is by far the rarest; there are only five in the Biltmore Forest collection. It probably was not used for bowling, since many of them are too large and too heavy to be handled easily. The second type, which is the most beautifully finished, is rarely found in other than perfect condition and so is regarded as "ceremonial." The last two types, however, are more often chipped or nicked at the edges than in perfect shape, which leads me to believe that they were used in their various games and that the beveled discoidal was especially made for use on alleys such as those uncovered at the Greenwood mound.

One of the interesting finds made close to the bowling alley was a discoidal of the beveled-edge type, from which one large piece had been chipped off. This fragment was discovered three days later at a point some fifteen feet away. Upon being placed in position on the original stone it showed clearly that, after the chipping off of the piece, the discoidal had been reworked by its owner. Also several discoidals were made of mica schist. These, of course, were very roughly finished, but were interesting because of the sparkle of the mica.

Before the bowling alleys, and especially the field rocks, had been completely uncovered and prepared for photographing a cloudburst caught us unaware. After the deluge we found that the symmetry of the squares had been largely destroyed, but, fortunately, I had drawn a sketch as the excavation progressed, and the photograph taken after the storm still gives an idea of the arrangement of the field stones and shows at least one of the decayed wooden borders (Pl. I, Fig. 2).

In American archaeology there are a great many artifacts of the Indians still classed as "problematicals," owing to the fact that we do not definitely know to what use they were put. This is primarily

due to the lack of any written history by these early Americans and to the rapidity with which they lost their own arts and adopted those of the white man upon contact with him.

Only through the good fortune of finding evidence, such as these bowling alleys at the Greenwood mound, is it possible for archaeologists to reconstruct the life and habits of the Indians prior to the coming of the white man. In this case the evidence was undisturbed owing to two facts: first, the Indians had evidently covered up these alleys before undertaking some expedition or temporary migration from which they expected to return; and, second, the owners of the land had plowed over the mound year after year from north to south, burying deeper and protecting more surely this prehistoric playground.

Cranbrook Institute of Science
Bloomfield Hills, Michigan

PLATE I

FIG. 1. The J. J. Greenwood mound near Dillard, Georgia, before clearing. Note the brambles and the cornstalks

FIG. 2. Squares of river stones associated with the clay runways. From a photograph taken after a cloudburst

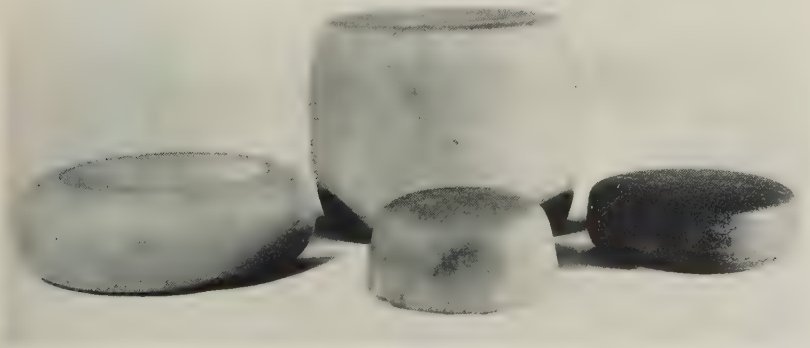


FIG. 3. Four types of discoidals

PREHISTORIC STORAGE PITS IN SAGINAW COUNTY, MICHIGAN

FRED DUSTIN

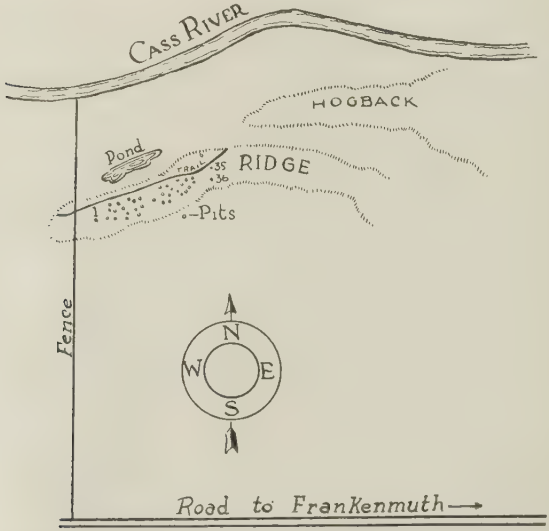
AMONG the interesting remains of the American Indian mentioned or described by early writers we find storage pits, usually spoken of locally as "corn pits." Though the latter designation is quite applicable, corn was only one of several foodstuffs thus stored.

In our own State of Michigan these evidences of prehistoric life and culture were numerous, and perhaps no county in the state had more of them than Saginaw, for its rich bottom lands were ideal for the cultivation of corn, while the sandy knolls and ridges that abounded afforded the situations best adapted to underground storage as practiced by the aborigines. Saginaw County was a populous center,[1] and early settlers and local historians have frequently noted large cornfields; in fact, the former often planted their first crops on land cleared perhaps hundreds of years before a white man saw this continent. The plow of the settler soon left its furrows on this cleared land, but the storage pits, usually located on light, poor soil, often escaped cultivation for years, and in this manner a few of these relics have survived destruction. It is such a group, possibly the only one left undestroyed in this county, which I have surveyed and platted and which I shall describe. It is located in the northeast quarter of the southwest quarter of Section 29, Frankenmuth Township, forty rods south of the Cass River, which bisects the section (see Map 1). A fraction of this quarter-quarter section lies north of the river. Of the major portion south of the stream only a narrow strip on its western border has ever been cleared; although the greater part was lumbered many years ago, it was allowed to become forested again and is now covered by a mixed growth of hardwood, with a considerable

[1] Dustin, Fred, "Some Ancient Indian Village Sites in Saginaw County, Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 12 (1929): 77. 1930.

number of small pines and a few larger ones. The original stand, which was mainly pine of good size and quality, formed beautiful groves on the higher grounds and river bluffs, ideal situations for aboriginal camps and villages, a fact attested by numbers of artifacts, pottery remains, and other relics of primitive days collected from several sites in the near vicinity.

On the eastern edge of the cleared land bordering this wooded tract a sand knoll rises abruptly from a little run (Pl. II, Fig. 1).

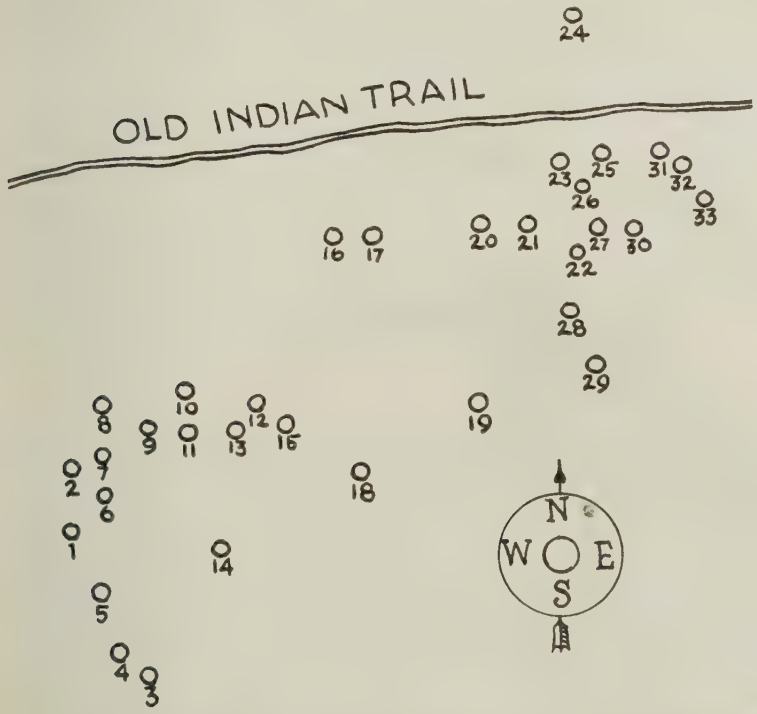


Map 1. Location of storage pits (indicated by dots) in Section 29, Frankenmuth Township, Saginaw County, Michigan (see also Map 2)

Near the crest of this elevation a stump fence divides the cleared land from the woods. Crossing this fence from the westward, we find ourselves thirty or thirty-five feet above normal low water in the river, and twenty feet above the bottom land northward. The little hill we have climbed is the terminus of a narrow ridge extending northeast and southwest; at its foot on the left is an intermittent pond two or three acres in extent, once a favored haunt of wild ducks and other waterfowl. One hundred feet east of the fence is the pit marked "1" on the plat (Map 2), with pit 2

a few feet north. Near these two pits, aided by my assistant, Mr. Ralph Stroebel of Saginaw, I ran a line north and south by compass, from which measurements were made with pit 1 as an initial point.

For four or five hundred feet northeast the ridge at its base is about two hundred feet wide and is composed of yellow sand.



Map 2. The storage pits shown on and along the ridge on Map 1. Eighty feet to the northeast of pit 33 is another prominent pit, 34 (not indicated on the map); one hundred feet east of it are two others, 35 and 36 (see Map 1)

Many woodchuck holes, both occupied and abandoned, with one hole freshly dug, showing a badger's tracks in the soil, were seen at the time of my survey, April 29, 1934. A pioneer settler who hunted and trapped hereabouts for forty years or more has told me he could usually find the tenement of a badger on this ridge

or near it. In studying the pits care should be used not to confuse the funnel-shaped depressions formed by the sand settling around the mouths of these abandoned animal burrows with those made by human hands.

Nearly all the storage pits are found along the flat crest of the ridge, most of them in two groups, with four scattered between and others to right and left. Pits numbered 1, 2, 6, 7, 8, 9, 10, 11, 12, 13, and 15 form the westerly group; those numbered 20, 21, 22, 23, 25, 26, 27, 28, 30, 31, 32, and 33, the easterly. About eighty feet northeast of pit 33 is another prominent pit, numbered 34, and a hundred feet farther in the same direction are two others, numbered 35 and 36. These last three are not shown on the plat, but, including them, there are, on a space sixty feet by three hundred feet, thirty-six attributable to the Indians, with a possibility of several more, for when they were questionable, I gave the benefit of the doubt to badger or woodchuck. There are also two or three "blowdowns," hollows in the soil, usually with a gravelike mound on one side, caused by roots of trees lifting the earth as they were overturned by the wind. In time, the decaying of trunks and roots left the hollows and mounds.

The Indian pits are shallow; the deepest are not over three feet after the leaves and the rubbish have been removed, for the sand has caved in and nearly filled the original excavations. They are circular in outline, although some have been marred by lumbering operations, as well as modified by natural causes and the treading feet of men and beasts. Mr. Stroebel removed leaves and débris from one or two, and I secured a fair picture of a typical depression; also a second photograph of it with Mr. Stroebel standing in it (Pl. II, Fig. 2). This pit is about two feet deep, but it is not possible to indicate depth with accuracy in such a view, so that it appears to be much shallower.

Owing to lack of time, we did not attempt to excavate any of the pits: if they are of the usual type, their depth would be five or six feet, and probably fragments of the bark linings would remain, with a possibility of securing some relic of stone, bone, or copper, for such articles were sometimes stored in these pits with other belongings.

On rising ground five hundred feet west of these corn pits I collected artifacts and potsherds from a small prehistoric village

PLATE II

FIG. 1. Knoll forming western end of ridge on which are located a number of Indian storage pits. Section 29, Frankenmuth Township, Saginaw County, Michigan

FIG. 2. One of the storage pits (No. 10 as shown on Map 2)

site, which is really the continuation of a larger one extending to this point from the southwest, and designated "Dead Creek Village," [2] formerly a very good collecting ground. Another interesting feature is a remnant of the old Indian trail on the ridge where the pits are located. In Plate II, Figure 1, at a third of the distance from the left, may be seen a small, forked, light-colored tree against a background of pines. A person who is walking up the river, either with purpose or aimlessly, naturally takes the easiest route, and therefore enters the woods near the forked tree. After traversing a hundred feet, he may realize that he has involuntarily followed the footsteps of the red man and is walking in his ancient path. In winter when the ground is covered with snow, or at a certain time in the spring, traces of this old trail are very perceptible, but with the abundance of summer vegetation it is hardly noticeable. It ascends gradually to the crest of the ridge, where it is lost, but if we continue our journey northeastward, we come to a run separating the storage pit ridge from another which terminates ahead of us in a long, pointed "hogback," with its extremity toward the west. The Indian trail crossed the run and followed up the hogback to higher ground beyond.

I have often traveled over this ground in the last twenty years, and have unconsciously followed the route of the primitive man who came before me, although my interest in the pits usually led me directly to the crest of the ridge. In the springtime a few years ago, while searching for the rare green-flowered trillium for a friend at the University of Michigan, I noted the faint old trail, some five feet below the summit of the ridge on its northerly side, and followed it each way until it was lost on the knoll or at the edge of the cleared field.

My attention was called to these storage pits in 1916 by Mr. Frank Satchell of Frankenmuth Township, who was the trapper and hunter mentioned on a previous page. To him and to Mr. Stroebel, who assisted me in the survey, I owe my thanks for information and help, and to Mr. John Kueffner for permission to enter upon his lands in doing the work.

Saginaw, Michigan

[2] See article cited in note 1.

FOLKLORE FROM THE HILLS OF SCHOHARIE COUNTY, NEW YORK STATE

EMELYN E. GARDNER

DURING the summers of 1912–18 I collected from the lips of folk living within an area about ten miles square in the hills of the southern part of Schoharie County, New York State, such traditional legends, tales, songs, games, riddles, beliefs, and customs as came to me through casual contacts and association. In 1919 the collection, while not in any sense exhaustive, appeared to be sufficiently representative to warrant a comparative study of it. The first step toward this consisted of a review of the history of the region in which the collection had been made that it might become evident what external events, what economic changes, what local personalities had been instrumental in bringing about such variations as might exist in Schoharie versions of European folklore and in producing any new or original folklore which the collection might contain.

The historical survey revealed that my informants were descendants of German Palatines and of Dutch, English, Welsh, French, Scotch-Irish, and Irish immigrants. During the eighteenth century these people settled in the fertile valley of the Schoharie River, which they bought from the Indians who owned it.[1] All the new settlers, except a few Negro slaves owned by the Dutch, were strongly Protestant in faith and democratic in spirit.[2] And these qualities are prominent in those of their descendants whom natural and social factors have driven to the hills surrounding the rich farm land of the Schoharie Valley which their ancestors owned and tilled. Here, almost entirely cut off from metropolitan markets by reason

[1] Cobb, Sanford H., *The Story of the Palatines* (New York, 1897), pp. 59–102; Simms, Jephtha, R., *History of Schoharie County and Border Wars of New York* (Albany, 1845), pp. 23–24, 31–34, 37–40, 54–55.

[2] Turner, Frederick J., *The Significance of Sections in American History* (New York, 1932), pp. 12, 293.

of bad country roads and the distance to a railroad, they contrive to wrest a scanty living from the poor limestone soil while they indifferently follow the folkways of their ancestors.

After a review of historical sources there followed a study of the folklore of those European countries represented by the eighteenth-century Schoharie immigrants and a study of folklore which had been collected elsewhere in the United States, particularly among the Pennsylvania Germans, the New Englanders, the white mountaineers of the southern Appalachians, and the Negroes of the South, all of whom are closely related historically to the Schoharie informants.[3] These comparative studies show that in a period covering approximately two hundred years, within a small area where a great deal of traditional lore is still current, very little new lore has appeared.

That little, in keeping with the theory of one school of folklorists, is geographical and historical in character. For example, there are no Schoharie Indian folk tales or myths which have not been collected elsewhere in identical form. But there are many place names which commemorate the red man's occupation of the Schoharie Valley. One of these, Schoharie, which is said to signify "driftwood," [4] is the name of a county, a town, a village, a river, and a tribe of refugee Indians which derived its name from the river. The Dutch and the German immigrants were also responsible for many place names. One of them is Feghtberg, which, translated, is "Fight Hill," an appropriate name for a hill where it is said that a fight took place among the members of the first company of white settlers entering the valley.[5] An eloquent memorial of these same Germans, who, in their trek over the mountain from the Hudson River Valley, stopped at a small creek for their first Sunday bath in their new home, is found in the suggestive name of that creek, Lousekill. The first part of the name which was given by the English, is self-explanatory; the second part, *kill*, is a seventeenth-century Holland-Dutch word which meant "connecting channel." [6] But in Schoharie County the word is in common use as a

[3] See note 2.

[4] Simms, *op. cit.*, pp. 22–23; Ruttenber, E. M., "Indian Geographical Names," *Proceedings of the New York State Historical Association*, VI: 207–208.

[5] Simms, *op. cit.*, p. 46.

[6] Reynolds, H. W., *Collections of the Dutchess County Historical Society*, I(1924): 71.

name for small streams, as Westkill, Minekill, Manorkill, Linekill, and so on.

Many tall tales are related of one Timothy Murphy, a tough, racy, and crude Schoharie pioneer, who achieved fame during the American Revolution for his ability to outwit the Indians who fought on the side of the British and who considered Murphy the Devil himself.[7] His reputation for having killed forty Indians single-handed places him in the tradition of Davy Crockett, "Gamecock of the Tennessee Canebrakes," Little Kit Carson, Wild Bill Hickock, and Mike Fink. Several local cliffs and caves have furnished the picturesque background for Timothy Murphy's exploits. But most of the tales are localized versions of the deeds of other heroes from King David, whose life, like that of Tim Murphy, was saved by a spider's web,[8] to "the Biggest Liar in the World," who, like Murphy, miraculously dug himself out of a rock into which he had sunk to his armpits.[9]

There are three crude local ballads relating to the outwitting of sheriffs during the Anti-Rent War of the 40's,[10] when the folk who lived on Blenheim Hill in Schoharie County refused to pay even nominal rent to descendants of old Dutch and English patroons who had received grants of land from their respective crowns.[11] There are also spirited stories of Robin Hood flavor which relate the half-humorous, half-heroic, but wholly successful, forms of resistance which the Schoharie tenantry set up against the scions of the law who were sent to collect rent during this same period.[12] Obviously, the Blenheim Hill folk did not intend, if they could help it by exercising their wits, to submit to the heavy taxation which had driven their grandparents from their native European homelands.[13] There is one exceedingly crude ballad relating to

[7] *Life and Adventures of Timothy Murphy* (The Middleburg Gazette, Middleburg, New York, n.d.).

[8] Henderson, William, *Notes on the Folklore of the Northern Counties of England and the Borders* (London, 1879), p. 312.

[9] *Folklore*, 4: 189.

[10] Cheyney, E. P., *The Anti-Rent Agitation in the State of New York, 1839–1846*, Publications of the University of Pennsylvania, Political Economy and Public Law Series, No. 2 (Philadelphia, 1887).

[11] McMaster, John Bach, *A History of the People in the United States from the Revolution to the Civil War* (New York, 1918), VI: 520–523.

[12] Mayham, Albert, *The Anti-Rent War on Blenheim Hill* (Jefferson, New York, 1906), p. 34.

[13] For references see note 1.

the intemperance of an early day-school and singing-school master which, according to factual history, would have been applicable to other early German and Dutch schoolmasters in Schoharie County.[14]

All these vulgar songs and stories of local origin are commonplace in material and weak in structure. It would seem that the eccentric old circuit rider, Lorenzo Dow, whose name is known on two continents [15] and who at one period is said to have included Schoharie County in his circuit, might have been responsible for some original stories. But of the two which are related of him, one, entitled "Raising the Devil," is a version of an old medieval Latin tale;[16] the other is an episode which is embodied in "The Arkansaw Traveller." [17]

That the number of informants who contributed to the collection one hundred and forty-three items pertaining to witchcraft was large is evidence that faith in witches and their activities still lingered in the Schoharie region in 1912–18. This is not surprising in the light of the tragedies recently enacted in the name of witchcraft in York County, Pennsylvania, where the people are historically related to those of Schoharie County.[18] Research shows that all the witchcraft items collected from the Schoharie informants are localized forms of similar European matter which, by reason of its wide dissemination in Europe throughout the eighteenth century, must have been familiar to the Schoharie immigrants of that period.[19] The few stories pertaining to ghosts contain the usual formulas of banging doors, lights, balls of fire, rappings, and the striking of a long-

[14] Goodwin, Maude W., *Dutch and English on the Hudson* (New Haven, 1919), p. 94.

[15] Sellers, Charles Coleman, *Lorenzo Dow, The Bearer of the Word* (New York, 1928).

[16] Ulrich, J., *Proben der lateinischen Novellistik des Mittelalters* (Leipzig, 1906), p. 200, No. 38, cited from Étienne de Bourbon, "Le Coy de la Marche," *Anecdotes historiques, legendes et apologues . . . d'Étienne de Bourbon* (Paris, 1877).

[17] Shoemaker, Henry W., *Mountain Minstrelsy of Pennsylvania* (Philadelphia, 1931), p. 252.

[18] For an account of a state-wide investigation of witchcraft and other forms of the black art introduced into southeastern Pennsylvania by early German settlers and practiced in 1928 by hundreds of York County people who were descendants of these Germans see *The New York Times*, December 1, 1928.

[19] Many sources were used, but two of those most helpful were the following: Kittredge, George Lyman, *Witchcraft in Old and New England* (Harvard University Press, Cambridge, 1929); Grimm, Jacob, *Teutonic Mythology*, translated by J. S. Stallybrass (London, 1880–88), 4 vols.

silent clock.[20] Tales of haunted houses have lost all vitality except the little which remains in mysterious lights and ghostly footsteps.

The twenty more or less coherent folk tales collected seem a goodly survival until it is noted that only five informants narrated tales, and that one of the five contributed fourteen of the twenty. Among the tales are one animal tale, a quaint version of the "Three Pigs," [21] and one giant story of the Perseus type.[22] Three of the tales belong to the Bluebeard cycle,[23] two to the Cupid and Psyche cycle.[24] Four fall under the Cinderella type,[25] two under the Little Fairly type,[26] two under the Grateful Dead type,[27] three under the Noodle type.[28] One is a story derived from an English ballad.[29] All, with the exception of the ballad story, are versions of tales in the collection of the Brothers Grimm, of which excellent comparative studies have been made by Bolte and Polívka in their monumental four-volume work, *Anmerkungen zu den Kinder- und Hausmärchen der Brüder Grimm.* Eight of the Schoharie tales are most closely analogous to German versions of similar tales, three to English variations of German versions; two are hybrid tales in which some elements most closely resemble German and others Irish versions of the tales. One runs close to a French and a Gypsy version of a Grimm tale.[30]

[20] Seymour, St. John D., and Neligan, Harry L., *True Irish Ghost Stories* (London, 1914).

[21] See Aarne, Antii, *The Types of the Folk-Tale, A Classification and Bibliography* (translated and enlarged by Stith Thompson), *FF Communications No. 74*, type 124; Bolte-Polívka, *Anmerkungen zu den Kinder- und Hausmärchen der Brüder Grimm*, Vol. I, No. 5. The former work is hereafter cited as "Aarne-Thompson."

[22] See Aarne-Thompson, *op. cit.*, type 300; Bolte-Polívka, *op. cit.*, I, No. 60.

[23] See Aarne-Thompson, *op. cit.*, types 311, 955, 956B; Bolte-Polívka, *op. cit.*, I, Nos. 40, 46.

[24] See Aarne-Thompson, *op. cit.*, type 425; Bolte-Polívka, *op. cit.*, I, No. 88.

[25] See Aarne-Thompson, *op. cit.*, types 480, 510, 900; Bolte-Polívka, *op. cit.*, I, Nos. 21, 24, 52; II, No. 65; Marian R. Cox, *Cinderella* (London, 1893).

[26] See Aarne-Thompson, *op. cit.*, types 1535, 1537; Bolte-Polívka, *op. cit.*, II, No. 61; William A. Clouston, "Little Fairly," *Popular Tales and Fictions*, II: 229–288.

[27] See Aarne-Thompson, *op. cit.*, types 326, 569; Bolte-Polívka, *op. cit.*, I, Nos. 4, 54; III, No. 200.

[28] See Aarne-Thompson, *op. cit.*, types 1245, 1286, 1384, 1415, 1450, 1476; Bolte-Polívka, *op. cit.*, I, Nos. 32, 34; II, Nos. 83, 104; III, No. 139.

[29] See "Crafty Kate of Colchester," *The Roxburghe Ballads*, edited by J. W. Ebsworth, VIII (Hertford): 430–431.

[30] See Groome, Francis H., "The Brigands and the Miller's Daughter," *Gypsy Folk-Tales* (London, 1899), pp. 168–175; Cosquin, Emmanuel G., "La Fille Du Meunier," *Contes de Lorraine*, 2 vols. (Paris, 1887), I: 178–185.

But the Schoharie "Cinderella" is a baffling hybrid, which is little more than a skeleton composed of elements from Finnish, Norse, Danish, Irish, Scotch, Spanish, French, and Italian versions of Cinderella.[31]

When compared with European versions of the same tales, Schoharie tales show marked thinness and incoherence. Two of them have retained only one of the several motifs in the most closely analogous European version. The weakness in form, the crude localizations, and the vulgar vernacular which prevail in the Schoharie forms of traditional European tales show that in place of development there are only the changes brought about by decay and degradation.

Having originally gone to the Schoharie hills in 1912 to gather old traditional ballads, many fine survivals of which were at that time being collected in the southern Appalachians from singers of the same racial stock and history as Schoharie folk, I was surprised to be able to find only twenty-nine traditional songs in addition to the four very crude local ones to which I have already referred. One is a variant of "Tom Bolin," which first appeared in *The Complaynt of Scotland* (1549).[32] Two, "The Dumb Wife" and "The Jolly Thresherman," are slight variations of seventeenth-century ballads.[33] All the other songs and ballads which I found are included in collections from the eighteenth to the late nineteenth century. Thirteen English songs were contributed by one aged informant, who in her younger days had been a local singing teacher. Internal evidence indicates that five of the songs are Irish. And two lullabies are slight corruptions of German and English originals. The fascinating folk history of Jephtha Simms, which contains most of what is known of the early history of Schoharie County, mentions wrestling, dancing, various kinds of games, and drinking as favorite diversions of the early settlers, but ballad singing, if there was any, goes without comment.

The fifty-eight games collected leave no doubt as to the popularity of that form of amusement, although every one of them is a form of some game found in collections of European and American

[31] Cox, *op. cit.*, Nos. 4, 9, 15, 16, 17, 25, 26, 30, 31, 33, 35, 37, 38, 42, 46, 47, 54, 57, 59, 93, 100, 151, 263.

[32] Baring-Gould, Sabine, Sheppard, H. F., and Bussell, F. W., *Songs of the West* (Fifth edition in one volume, London, 1917), pp. 13, 84–85.

[33] *The Roxburghe Collection*, II : 112; Kittredge, George Lyman, *The Journal of American Folk-Lore*, 30 : 353–355.

games.[34] The absence of new games in a locality where traditional ones are so popular that they are played not only by children but also by adults is eloquent testimony of poverty of invention and of toughness of tradition.

The one hundred and thirteen riddles of the collection indicate that riddling is as popular with Schoharians as it is with the Pennsylvania Germans and the Nova Scotians, all peoples of the same history.[35] One of the Schoharie riddles harks back to a riddle propounded by King Solomon;[36] eleven of them are based on the same subjects as ten of the riddles in the collection of Symphosius, thought to have been written during the third or the fourth century A.D.;[37] eight are riddles collected in England about the middle of the seventeenth century; and fifty have solutions similar to riddles in the third edition of *Das Rätselbuch*, by Karl Simrock.

Not one item of the three hundred and seventy-seven general folk superstitions of the collection has any claim to originality. Research shows that the many teas or watery infusions prescribed for various disorders are survivals of the Anglo-Saxon use of simples,[38] a form of medicine which Cockayne considers to have been derived from Greece and Rome. The cures based on the belief that disease is caused by evil spirits,[39] that it may be transferred or cured by the exercise of magic,[40] are analogous to cures in Roman, Scotch, English, German, Pennsylvania German, and American Negro collections of folk medicine and other types of folklore as well as to similar cures of primitive peoples discussed in J. G. Frazer's *The Golden Bough* and William Crooke's *The Popular Religion and Folklore of Northern India.*

Although there is little original matter in the entire collection, the great number of survivals indicates that many of the folk of

[34] Gomme, Alice B., *The Traditional Games of England, Scotland, and Ireland*, 2 vols. (London, 1894, 1898); Newell, William W., *Games and Songs of American Children* (New York, 1883).

[35] Fauset, Arthur Huff, *Folklore from Nova Scotia* (New York, 1931), pp. x, 140–176; Stoudt, Reverend John B., *The Folklore of the Pennsylvania Germans* (Philadelphia, 1916).

[36] Judges xiv. 14.

[37] Ohl, Raymond T., *The Enigmas of Symphosius* (Philadelphia, 1928).

[38] Payne, Joseph F., *English Medicine in the Anglo-Saxon Times* (Oxford, 1904), p. 49.

[39] *Ibid.*, p. 115; Black, William G., *Folk-Medicine* (London, 1883), pp. 4–25.

[40] Black, *op. cit.*, pp. 49–64.

the Schoharie hills, who are descendants of generations of such folk, are thinking and believing in the primitive way and in the primitive degree, that they, like others of the same racial stocks in similar environment, are not attuned to the civilization around them. Local geological and geographical factors have brought about social and economic conditions which have influenced the psychology of these folk, which in its turn not only has retarded their material and spiritual progress, but also has brought about unmistakable signs of decay in both the folk and their folklore.

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SOME CHIPPEWA AND OTTAWA USES OF SWEET GRASS

VOLNEY H. JONES

FOR several weeks during the summers of 1933 and 1934 I was engaged in a study of the methods of preparation and utilization of plant products by the Chippewa and Ottawa Indians.[1] While visiting several communities in Michigan and Ontario for this purpose I had the opportunity to witness the gathering and preparation of sweet grass by the Indians and its applications in their handicrafts.

Sweet grass, *Hierochloe odorata* (L.) Beauv., is of the grass family (Gramineae), and hence is properly called a grass. It has been known under several synonymous scientific names, some of which are *Hierochloe borealis*, *Savastana odorata*, and *Torresia odorata*. It has likewise received several common names; among those best known are Seneca grass, vanilla grass, and holy grass. It should not be confused with sweet vernal grass, *Anthoxanthum odoratum*, a closely related grass of somewhat similar appearance and properties.

This grass is native to both the Eastern and the Western hemispheres. On the continent of North America its range is very widespread across the northern regions. According to Hitchcock (3, pp. 527–528), it occurs in "Meadows, bogs, and moist places, Labrador, to Alaska, south to New Jersey, Indiana, Iowa, Oregon, and in the mountains to New Mexico and Arizona . . . ." It formerly was quite common in swales and along lake margins throughout the Great Lakes region. Two other species of this genus occur in North America, but I am not aware that either of them or the sweet vernal grass has been put to any use by Indians. Under

[1] From July 3 to September 9, 1933, as the Homeopathic Hospital Guild Scholar in Michigan Ethnology of the University of Michigan; and from August 1 to August 20, 1934, with the aid of a faculty research grant from the same university.

the name *Anthoxanthum odoratum* Huron Smith (7, p. 419) reports the use of sweet grass by the Ojibwe (Chippewa) of Wisconsin, but obviously this is an error, for the Chippewa name as given by him agrees exactly with that given by Densmore (1, p. 294) for *Hierochloe odorata* (under synonym, *Torresia odorata*). Further, the plant could not be Anthoxanthum, since, according to Smith, it was used ceremonially in olden times, whereas Anthoxanthum is a recent introduction from Europe. The plant which Smith discusses must be *Hierochloe odorata*.

Sweet grass is a semierect grass that seldom reaches a height of over two and one-half feet, usually growing among shrubs or among other grasses. It is not often found in pure stands. It is a perennial from creeping rootstocks. The low and inconspicuous fruiting stalk appears early, producing seed in June or early July. The leaves of this stalk are few, short, and with long sheaths and short blades; consequently they are of no use to the Indians. The long, flexible leaves which develop later from the sterile shoots are the ones which are desired.[2]

To the average person sweet grass is not at all conspicuous, since it is low and is usually intermingled with other plants. It is, however, immediately recognized even from some distance by the Indians who are accustomed to gathering it. It is so familiar to them that my first questions in regard to the particular characters by which they know it received very unsatisfactory answers; they simply knew it when they saw it. Further questioning elicited the information that the glossy upper surface of the leaves and the semierect habit are features useful in its recognition.

The grass is harvested from the middle of July until it begins to dry in September. Several harvests are made, but the mid-season product is considered most desirable. The leaves are gathered by grasping the shoots firmly near the ground and pulling steadily until they break loose from the rootstocks, which are an inch or two under the surface. Careless jerking is liable to break the shoots above the ground and to leave ragged ends and cause waste. Gathering is slow and tedious since the grass is usually scattered and mixed with other plants. Much of the gathering is done casually in passing, but at the height of the season an entire

[2] For descriptions, illustrations, and distribution of sweet grass and closely related species see Hitchcock's treatment (3, pp. 526–535) of the tribe Phalarideae.

family may go out for a day or two to harvest a supply to be stored for use during the winter.

I have been told that sweet grass is often planted to assure a more convenient and more plentiful supply. I saw a very good stand of it in a field near an informant's house on the Walpole Island Reserve in Ontario. He explained that this had been started by his father-in-law, who had transplanted rootstocks several years before. Care had been taken to plant these in a damp place among other plants, where the young shoots would have shade. No subsequent cultivation or care had been given to the plants. An article in the *Ann Arbor Daily News* of July 7, 1933, with a Pellston, Michigan, date line, gives an account of the "cultivation" of sweet grass by the Indians (Ottawa?) near that city to supplement the wild supply. According to the article, "It has been discovered that cultivation improves the quality of the grass as well as increases the quantity a given area will yield." I have not seen the cultivated grass near Pellston; therefore I do not know how intensive the cultivation may be, but I have been assured on good authority that plantings of pure stands in the open do not fare well. In other attempts to supplement the natural supply, so far as I have heard of them, only transplanting was practiced, and no claims of an improved product were made.

When growing or when freshly harvested sweet grass has a bright green color and very little odor. As it dries the color fades, and a delicate odor similar to that of vanilla is given off. If the grass is allowed to dry quickly in the sun the color and the odor are soon lost, and the grass becomes stiff and brittle. Some of the color, odor, and pliability can be retained for two or three years if the grass is properly cured immediately after gathering. The methods of curing vary. When only a few handfuls are brought in they are usually hung out of doors in the shade to dry slowly. This seems to be the only method practiced at the Ottawa community of Wikwemikong on Manitoulin Island. After thus drying, the grass is stored until used, when it is dipped into boiling water and withdrawn almost immediately. This restores the pliability and brings out the odor.

The Chippewa on Walpole Island have a process which, although certainly not aboriginal, is more thorough and seems to give a better product. Immediately after gathering the grass is

laid on top of a large flat-topped wood stove, which is just a little too hot for the hand to bear if laid upon it. The grass is spread thinly and evenly over the stove and shuffled with the hands so that it may cure uniformly. It is heated in this manner until the leaves curl and become convolute, which requires about ten minutes. The grass is then removed and tied in bundles, which are suspended from the rafters with their ends hanging close to the stove, but not touching it. A hot fire is built and allowed to die slowly, the grass being left over the stove as long as the stove is warm, which is for most of the day. The grass is then removed, wrapped tightly in newspapers, and put in a dark place, from which it is taken as needed. I saw grass which had been prepared in this manner and which, it was claimed, was two years old. The color and the odor were good, and the grass was sufficiently pliable to be used without dampening. Usually grass is not kept so long, however; most of it is consumed during the winter after the harvesting and curing. A small bundle of cured sweet grass is shown in Plate III, Figure 1.

The active principle of sweet grass which causes its pleasant odor is cumarin (or coumarin), which is classed as an essential oil, although it is a solid at ordinary temperatures. It has an odor and a flavor very similar to those of vanillin, the flavoring principle of the vanilla bean, hence the name vanilla grass.

Sweet grass was and is employed widely by Indians as perfume and incense almost everywhere that it is available. In the Plains region, where perfumes were more used than elsewhere, it seems to have been of first importance. According to Teit (8, p. 86), the Salishan tribes of the western plateaus utilized it in the same manner. In addition to the high place held by sweet grass as a personal perfume it was also an object of great religious veneration among some tribes, particularly those of the Plains region. It entered into the ritual of the Sun Dance, the Hako, and other ceremonies; in purification of participants, as incense; and in smoking. The fragrance of the grass doubtless suggested these uses.

It is of interest to note that sweet grass is connected with religion in northern Europe also. There it is known as holy grass, from the custom of strewing it before church doors on saints' days. Gilmore (2, p. 66) reports that the Dakota Indians who are members of the Christian Church attach sweet grass to palms which

are received at church on Palm Sunday, or carry it to church for this service. This might appear to be a practice introduced along with Christianity, since this grass was associated with the church in Europe. However, it is more likely, as Gilmore suggests, to be a relic of ancient Dakota beliefs and to persist because associated with their newly adopted religion.

The applications of sweet grass as perfume and as incense in ceremonies apparently were concentrated in the Plains region, but in the past must have extended into the Woodlands and must have been practiced by the Chippewa. Densmore (1, pp. 380-381) tells of the former use of it in these ways by the Chippewa of Minnesota and, according to Smith (7, p. 419), the Wisconsin Chippewa employed it ceremonially in olden times. I learned of no such practices by the Indians whom I visited, but they probably existed formerly and may have been lost in the almost complete conversion of these people to Christianity and European customs. I found no mention of the grass in Hoffman's account (4) of the Midewiwin or Grand Medicine Society, but this may have been an oversight of his or of mine.

The uses of sweet grass which I observed and of which I was able to learn among the Chippewa and the Ottawa of Michigan and Ontario were all of a material and practical nature in handicraft. The manufacture and sale of sweet-grass work, splint baskets, birch-bark products, and porcupine-quill work is the chief source of income in many of the communities. Some households are built around the gathering and preparation of materials and the manufacture of these objects. There is usually a division of labor among individuals of a family or among households; some persons do nothing but gather materials while others manufacture them. In the well-knit economy dependent upon this industry there is a lively trade in both raw materials and finished products. Active buying and selling take place within the community, and often when the local supply of some material has become largely depleted it may be replenished by traders from other places. At Walpole Island sweet grass is commonly sold within the reserve, although it still grows there in sufficient quantities. The price is standardized; a bundle of the cured product about two inches in diameter sells for twenty-five cents. At the Ottawa village of Peshabestown, Michigan, the grass has become so scant that al-

most the entire supply is brought in from elsewhere. I was told that cured grass sells there for two dollars per pound, and observed that it is handled and used with great care. Similar trade must occur among the Chippewa of Wisconsin, for Smith (7, p. 419) says: "While Sweet Grass is scarce around the Flambeau and Pillager reservations, they secure it elsewhere for making baskets . . . ."

The uses of sweet grass among the Indians of the Great Lakes region are of two general types: (1) in weaving grass on a splint foundation and in trimming splint baskets and bark objects, and (2) in making coiled objects sewed with thread. The uses will be discussed in this order.

Ash-splint baskets are commonly manufactured throughout the region which I visited. They are woven of splints from black ash, with handles and rims of black ash or hickory. The rim and the border are lashed on spirally with slender, flexible strips of ash. The larger baskets and those designed for heavy duty always have this border of ash, but in the smaller sizes and in fancy ornamental types sweet grass is almost always used. Plate III, Figure 2, shows a small ash-splint basket with a sweet-grass border. The reason for the use of sweet grass in this manner is that it is more pliable and plastic than ash. The better working qualities of the grass enable the finishing touches to be made more smoothly and more rapidly. The completed product has the added virtue of the fragrant odor of the grass, which, the Indians assure me, aids in the sale of the baskets. Observation seemed to bear out their statement.

The use described above is the most common one to which the grass is put, and a much greater quantity of it is consumed in this manner than in any other. Probably at least half of the splint baskets made in the Great Lakes region have sweet-grass borders. For this purpose the grass is ordinarily used in its natural color, but sometimes, if it has faded or if the desire is to have it match some green color in the color pattern of the splints, it may be dyed green with commercial aniline dye. I have never seen it dyed any color but green.

Ornamentation and embellishment are often added to the smaller fancy splint baskets and birch-bark objects in the form of handles, fastenings, designs, and trimmings. These frequently are of sweet grass and are sewed to the baskets with commercial cotton thread.

The grass used in this manner, as was the case with the borders, may or may not be dyed.

A rather common practice is the weaving of strands of braided or twisted grass on a foundation of splints. This form of wickerwork is also practiced by some of the Algonkian tribes of New England, according to Weltfish (9, p. 459) and Mason (5, p. 374 and Pl. 119). The braiding is usually of the common three-strand type. The twisting is done by rolling dampened grass on the thigh under the palm of the hand in the manner in which cord is made from fiber. The basket in Plate III, Figure 3, illustrates braided grass woven on a splint foundation, and also shows an ornamental tab of braided grass. The grass used in the construction of this basket had been dyed.

The only style of coiled basketry manufacture which has persisted to the present day in the Great Lakes region is that which is built up with a foundation of sweet grass sewed with commercial cotton thread. This technique, which is centralized among the Algonkian of the Great Lakes region, is practiced widely by the Ottawa and the Chippewa of Michigan and Ontario. The most common form is the trinket basket (Pl. IV, Fig. 1), but others such as mats and novelties are regularly made. These objects may be either entirely of sweet grass or built on a center or base of birch bark. Sometimes boxes of birch bark are finished with a few coils of grass. These and the mats with bark centers are ordinarily decorated with porcupine quills. The combinations of bark, quills, and grass are varied and infinite. Plate IV, Figure 4, shows a tray made with a birch-bark center decorated with quills, with sweet grass coiled around the outside. A recent innovation at Walpole Island is the fashioning of a basswood foundation for the tops of trinket baskets. Holes are drilled in the edges of this so that the grass may be sewed to it. A burned or a painted design usually ornaments the wood.

The equipment for this coiling is just what would be used by the average seamstress for ordinary sewing. It consists of small scissors, steel needle about one and one-half inches long, thimble, and commercial No. 10 black cotton thread. Before use the thread is drawn over a piece of beeswax. I was told that this operation was to cause the thread to pull through the grass more easily and thus to prevent the catching and breaking of the thread. It doubt-

less also preserves the thread. Cured grass is always used. It is often dampened to make it more pliable, but if it has been properly cured dampening is not necessary.

The sewing of sweet grass is usually done by the women, but I have seen one man who does coiling and produces objects of good quality. The work is generally carried on indoors. The workman is seated and has a table or other support for materials and equipment. The needle is threaded, and one end of the thread is knotted, so that it may be used for single-strand sewing. A small bundle of the grass about one fourth of an inch in diameter is taken; the ends are evened and the coarse bases cut off with the scissors. If the coil is to be entirely of grass, the base end of the bundle is knotted by looping the end over the bundle and pulling it through. The first coil is started by wrapping the long end of the bundle around this knot. The sewing is first through the knot, looping the thread around the long end of the grass, and back through the knot. As each stitch is made the grass is bent firmly against the knot and the thread pulled tight. After the grass has completely encircled the knot, the sewing is into the previous coil instead of into the knot. If a center of bark is used, no knot in the grass is necessary. The grass is laid against the edge of the bark and sewed to it. The sewing is through the edge of the bark, with the thread looped around the bundle of grass as before.

The object is held in the left hand; the needle is manipulated with the right. The smooth or work side is toward the worker; the rough or nonwork side is away from the worker. The first coil around the knot is made so that the free end of the grass below the knot is toward the nonwork side. As the sewing progresses the object is revolved, with the hands moving horizontally from right to left; thus, viewed from the work side, the coil is counterclockwise. The edge of the object is held between the palm and the index finger. The free end of the grass is held between the remaining fingers and the palm. The coil is manipulated and forced into place between the index finger and the thumb. The major part of the skill and finesse is in this manipulation, since the smoothness, firmness, and shape of the product depend upon it. In the manufacture of some objects such as flat table mats little shaping is necessary, but in the making of trinket baskets and some novelties great skill is required.

Each stitch is completely around the free end of the grass and approximately halfway back into the previous coil and under a stitch of the last round, so that the stitches of one round interlock with those of the previous round. On the work side the rows of stitches thus appear as many continuous radii from the center (Pl. IV, Fig. 2). The stitches at first are very close together, but as the operator works outward from the center — the diameter of the circle becomes larger — they become progressively farther apart. When they become as much as three eighths of an inch apart a stitch is made midway between two of the previous round, and thus a new radius is begun.

The grass leaves are ordinarily about eighteen inches in length. After a bundle of these has been sewed into the coil until only about six or eight inches are left, the bundle begins to become thin, since not all the leaves are of the same length. A number of new leaves are selected and placed together with their bases in the same direction. This new bundle must equal approximately the diameter of the previous one. The basal ends of the new bundle are carefully worked in among the upper ends of the last one, so that the splicing does not show from the work surface, and sewing is continued. At the completion of an object the free end of the bundle of grass is sewed smoothly and firmly in place against the previous coil.

Tops for the trinket baskets are made separately and hinged with thread, or a flange of birch bark may be sewed to the lid so that it fits into the neck of the basket and thus makes the lid removable. Many modern novelty shapes of coiled work are made, such as trays, table mats, kettles, and cups and saucers. A basket and a tray are shown in Plate IV, Figures 3–4. Birch-bark boxes and splint baskets are sometimes trimmed with a few coils of sewed grass rather than with a single bundle lashed to the edge. The lid of the basket in Plate III, Figure 3, has such trimming. The variations and combinations of coiled grass, birch bark, and splints are almost unlimited. Some very ornate trinket baskets combining coiled sweet grass, braided sweet grass, birch bark, and porcupine quills are shown by Skinner (6, pp. 296–297). These are of Menomini manufacture.

It would be difficult to estimate the antiquity of the uses of sweet grass described above or to speculate with any degree of

accuracy upon the extent to which these uses have been modified by the contact of the white man with the Indian. We may be sure that the white man's demand for novelties and souvenirs has been a very important factor in influencing these crafts. There is good reason to believe that the entire splint-basketry complex is of recent acquisition by the Algonkian Indians, so that the uses of sweet grass in this connection have not been practiced for any great length of time. Certainly the trimming of birch-bark objects with sweet grass and the manufacture of novelty coiled baskets has every appearance of being a recent innovation. Practically all the modern handwork of these Indians is designed for sale, and little is intended for their own use.

The basic technique of the coiling, however, has every appearance of greater age. It was practiced in every community which I visited and shows great uniformity throughout the region. The equipment of needle, thread, thimble, and beeswax is obviously not a part of the indigenous complex, but everything else seems aboriginal. According to Mason (5, p. 219), very old baskets of coiled sweet grass sewed with sinew are preserved in collections. He does not state specifically by what tribes they were made, but he discusses them along with products of the Algonkian. He compares these with Eskimo grass baskets sewed with sinew. Mason (5, pp. 376–377) gives Willoughby as his authority for the age of sweet-grass coiling in the Great Lakes region: "Charles C. Willoughby, of the Peabody Museum, Cambridge, Massachusetts, is of the opinion that coiled basketry was used among the Ojibwa Indians (Chippewa) on the Great Lakes before contact with the whites, and mentions very old specimens now in the possession of that museum, and others have been seen in private collections. The foundation coils are of sweet grass and about one quarter of an inch in diameter. In some of the old specimens the sewing is done with looped stitches, being continuous from the edge toward the center of the basket and not following the coils as is usual."

I have seen no baskets of the old type noted by Willoughby, but there is evidence that still other types of coiled basketry formerly existed in eastern North America. Weltfish (9, p. 471) described an old Miami basket sewed with bark thread, and a set of Chippewa disks of single-rod foundation, which are in the Museum of the American Indian. Neither of these types is made

at present among the Algonkian. It seems that there was formerly more diversity of types of coiling in the eastern region, but that the technique which has been described in this paper is the only one which has persisted to the present time.

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LITERATURE CITED

1. Densmore, F. Uses of Plants by the Chippewa Indians. Bureau of American Ethnology, Forty-fourth Annual Report, pp. 275–397. Washington, 1928.

2. Gilmore, M. R. Uses of Plants by the Indians of the Missouri River Region. Bureau of American Ethnology, Thirty-third Annual Report, pp. 43–154. Washington, 1919.

3. Hitchcock, A. S. Manual of the Grasses of the United States. United States Department of Agriculture, Miscellaneous Publication No. 200. Washington, 1935.

4. Hoffman, W. J. The Midewiwin or Grand Medicine Society of the Ojibwa. Bureau of American Ethnology, Seventh Annual Report, pp. 143–300. Washington, 1891.

5. Mason, O. T. Aboriginal American Basketry; Studies in a Textile Art without Machinery. Report of the United States National Museum, 1902, pp. 171–548. Washington, 1904.

6. Skinner, A. Material Culture of the Menomini. Indian Notes and Monographs, Museum of the American Indian. Heye Foundation, New York, 1921.

7. Smith, H. H. Ethnobotany of the Ojibwe Indians. Bulletin of the Public Museum of the City of Milwaukee, 4 (1932) : 327–525.

8. Teit, J. A. The Salishan Tribes of the Western Plateaus. Bureau of American Ethnology, Forty-fifth Annual Report, pp. 23–396. Washington, 1930.

9. Weltfish, G. Prehistoric North American Basketry Techniques and Modern Distributions. American Anthropologist, 32 (1930) : 454–495.

PLATES III–IV

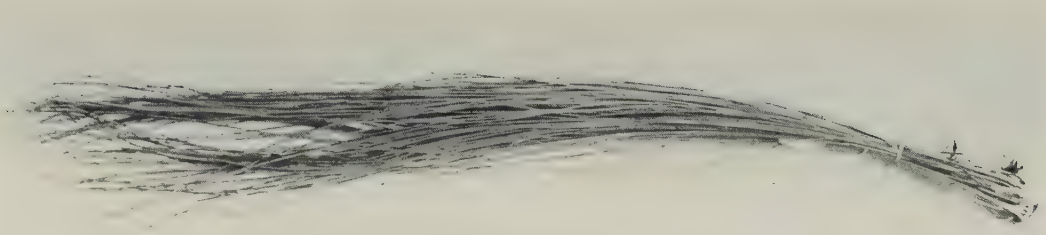


FIG. 1. Bundle of cured sweet grass, ready for use

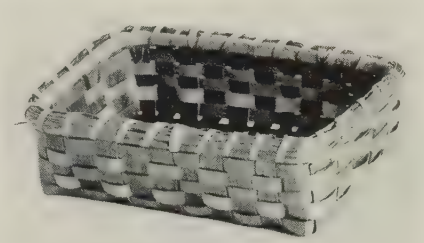


FIG. 2. Small splint basket with sweet-grass border

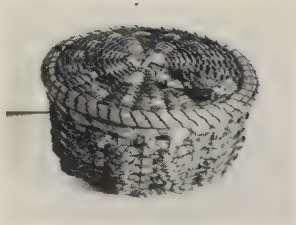


FIG. 3. Small basket with braided sweet grass woven on splint foundation, and with sweet-grass tab and rim

USES OF SWEET GRASS BY THE CHIPPEWA OF WALPOLE ISLAND, ONTARIO

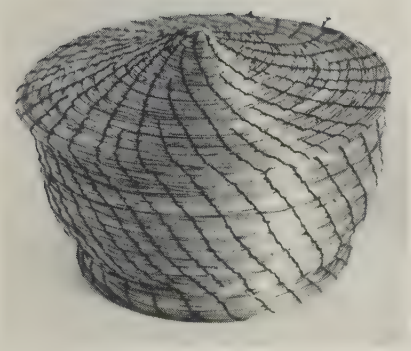


FIG. 1. Trinket basket made of sweet grass, in coiled technique, sewed with cotton thread. Chippewa of Walpole Island, Ontario

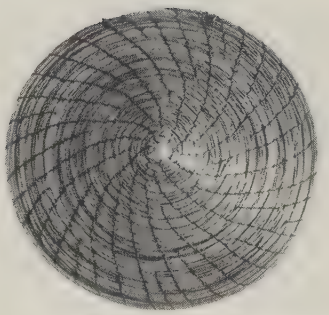


FIG. 2. Top view of the same basket, showing detail of sewing

FIG. 3. Coiled novelty basket made of sweet grass. Ottawa of Wikwemikong, Manitoulin Island, Ontario

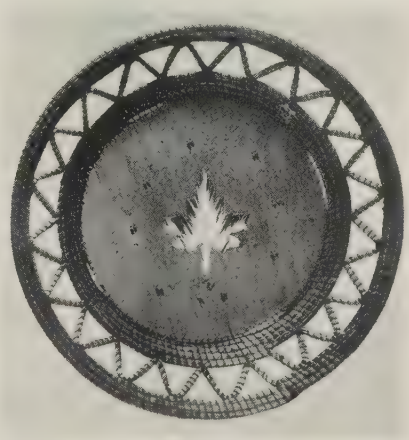


FIG. 4. Tray made with birch-bark center ornamented with porcupine quills; sweet grass coiled around outside. Ottawa of Wikwemikong, Manitoulin Island, Ontario

INFLUENCE OF POSITION ON STRUCTURE OF INFLORESCENCES OF *ZIZIA AUREA*

WILLIAM DOWELL BATEN

Part I

INTRODUCTION

WHILE the writer was examining the number of pedicels per umbel of *Zizia aurea* during the early summer of 1931, he soon discovered that the first umbel to bloom contained fewer pedicels than did later ones, and that the umbels blooming first were at about one half to two thirds of the height of the plants above the ground. With this in mind he decided to make a more detailed study of the first inflorescences as compared with the next two to bloom.

During the summer of 1932 the pedicels on the umbels of 507 plants of this species were counted, arranged in frequency distributions, and analyzed in several details. The first umbel to blossom proved to be the terminal of the main stem; the next two were terminals of the two branches just below the stem terminal. Stem-terminal umbels will be designated by T; the branch terminals by A and B. So far as could be determined, A and B bloomed about the same time, which was several days after T had bloomed. The positions of these three inflorescences are shown in Plate V. Notice that T is below the axillary terminal inflorescences and is an older inflorescence.

These plants, which were growing among much vegetation and tall grass, were found along the Huron River Drive about five miles from Ann Arbor, Michigan. Most of them produced three clusters, many had only two, and a few had four or five. The small number of clusters was due, no doubt, to the crowded habitat in which the plants were growing.

The objects of this article are to compare distributions of the number of pedicels per inflorescence for inflorescences at different

positions on the plants and to show the influence of position on the structure of inflorescences.

ANALYSIS OF THE 1932 SAMPLE

TABLE I

FREQUENCY DISTRIBUTIONS OF PEDICELS PER INFLORESCENCE FOR UMBELS T, A, AND B

No. of pedicels per umbel	Plants with three umbels			Plants with only two umbels		Plants with two or three umbels	
	Frequency			Frequency		Frequency	
	T	A	B	T	A	T	A
7	1	...	...	...	...	1	...
8	4	...	...	3	...	7	...
9	12	...	1	2	...	14	...
10	30	4	3	4	...	34	4
11	39	5	2	13	1	52	6
12	62	8	17	9	8	71	16
13	79	35	20	27	8	106	43
14	56	39	41	15	18	71	57
15	44	57	55	15	20	59	77
16	37	93	92	5	18	42	111
17	15	53	47	6	11	21	64
18	8	40	44	6	15	14	55
19	5	30	30	4	8	9	38
20	1	16	18	1	3	2	19
21	1	6	11	1	1	2	7
22	...	4	7	...	...	...	4
23	1	2	4	1	...	2	2
24	...	2	1	...	1	...	3
25	...	...	2	...	...	...	...
26	...	1	...	...	...	...	1
Total	395	395	395	112	112	507	507
Mean	13.27	16.15	16.37	13.83	15.76	13.39	16.07
S.D.	2.87	2.40	2.54	2.76	2.30	2.52	2.38

From these computations for plants with T, A, and B, it is seen that the average number of pedicels per stem umbel is 13.27 and that the averages for the first and second axillary terminal umbels are 16.15 and 16.37, respectively. These figures show that on the average stem clusters produce fewer pedicels than do axillary terminal clusters. There are significant differences between means for stem umbels and axillary terminal umbels; the difference be-

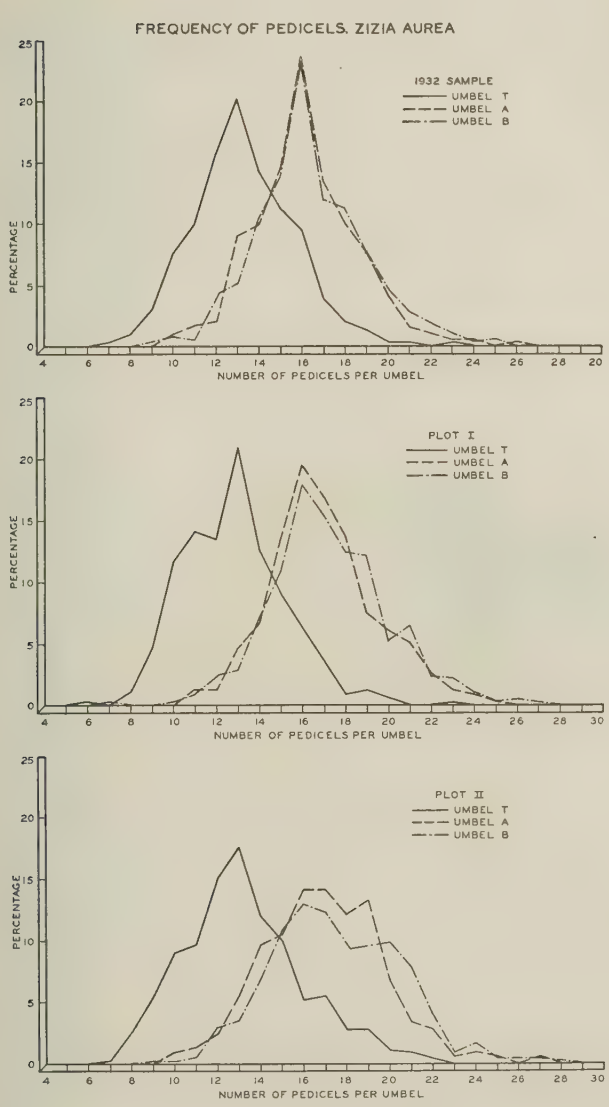

FREQUENCY OF PEDICELS. ZIZIA AUREA
1932 SAMPLE
UMBEL T
UMBEL A
UMBEL B
PERCENTAGE
NUMBER OF PEDICELS PER UMBEL
PLOT I
UMBEL T
UMBEL A
UMBEL B
PERCENTAGE
NUMBER OF PEDICELS PER UMBEL
PLOT II
UMBEL T
UMBEL A
UMBEL B
PERCENTAGE
NUMBER OF PEDICELS PER UMBEL

FIGURE 3

tween the means for axillary umbels is not significant. The first inflorescence to bloom produces on the average fewer rays than do those terminal inflorescences which bloom later. This is not true of certain other species in the umbelliferous family.

The differences between the distributions of the number of pedicels per umbel for stem clusters and axillary terminal clusters can be seen more clearly by examining the 1932 sample in Figure 3, which gives in percentages frequency polygons for the three distributions for plants having T, A, and B. The polygon on the left represents frequencies for stem umbels; the two on the right designate frequencies for terminal axillary umbels. Most of the distributions for T lie to the *left* of fifteen pedicels; most of those for A and B lie to the *right* of fifteen. This figure also reveals similarities of distributions for axillary terminal inflorescences. Here the means are nearly the same; the polygons are about the same in range, height, and general appearance, which indicates that there is little difference between distributions for axillary umbels. These diagrams clearly show that axillary terminal umbels produce more rays than do stem umbels.

There were 112 plants with only T and A umbels. Questions arose whether there were significant differences (*a*) between the means for T and A for these plants, (*b*) between stem umbels for plants with only one axillary terminal umbel and for plants with two axillary terminal umbels, and, finally, (*c*) between first axillary clusters for plants with only one axillary cluster and plants with two.

The significance of the difference of the means is

$$\text{Significance} = \frac{\text{Difference of the means}}{\text{Standard deviation of the difference of the means}}.$$

For (*a*) this is 5.7, which shows that there is significance between these means; there is no significance between the means in (*b*) and also none between the means in (*c*).

CORRELATION COEFFICIENTS

One naturally desires to know whether there is any correlation between the number of rays per inflorescence for stem and branch inflorescences. For plants with three inflorescences Pearson linear correlation coefficients and standard errors are as follows:

$r_{TA} = 0.433 \pm .036$ for plants with three clusters;
$r_{TA} = 0.350 \pm .044$ for plants with two clusters;
$r_{TA} = 0.399 \pm .042$ for plants with either one or two clusters;
$r_{AB} = 0.747 \pm .022$.

These correlation coefficients indicate that there is some correlation between the number of pedicels per umbel for T and A, but not so much as between A and B. The last coefficient indicates that, if the first axillary terminal cluster has a large number of pedicels, the second axillary terminal cluster will also have a large number of pedicels, and if the first has a small number, so will the second axillary cluster, etc.

Part II

Introduction

Since there was found to be a significant difference between stem-terminal and first and second axillary-terminal umbels, it was decided to make a more detailed study of this species and to seek more information concerning the structure of umbels for stem and branches. Samples were gathered from two plots; counts of pedicels were made for *every* umbel on the plants; and each distribution of the number of pedicels per umbel was analyzed in several details.

Plot I, which is on the Huron River Drive about five miles from Ann Arbor, Michigan, contained much vegetation growing in a very moist soil; Plot II, which is on a roadside about three miles south of Dexter, Michigan, contained very little vegetation growing in soil which was much drier than that on Plot I. Plants on Plot II were more in the open than those on Plot I. All plants on Plot II were gathered.

Both plots produced plants having branches with as many as three umbels. The letter A represents, as before, terminal umbels on the first branch below the stem umbel; A1, first nonterminal umbels on the first branch below the stem terminal; C2, second nonterminal umbels on the third branch, etc. Plate V shows a plant which has these umbels, with their proper labels. The first branch has two clusters; the second, three; and the third, only two. Notice the size of T in comparison with A, B, and C; also that clusters A1, B1, and C1 are later blooms than T, A, B, and C.

TABLE II

FREQUENCY DISTRIBUTIONS OF UMBELS FOR BOTH PLOTS

No. of umbels per plant	Frequency or no. of plants	
	Plot I	Plot II
2	4	7
3	183	159
4	108	154
5	105	65
6	55	43
7	30	18
8	10	19
9	11	9
10	1	7
11	5	2
12	...	1
13	...	1
Total	512	485
Mean	4.488	4.466
S.D.	1.646	1.761

On the average, plants on each plot produced about 4.5 umbels. Figure 4 exhibits frequency polygons for these two distributions. There were but four plants on Plot I and seven on Plot II which

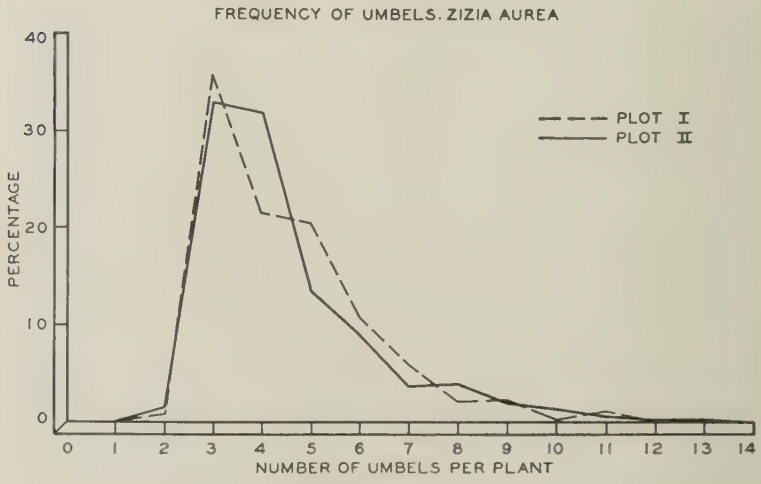


FIGURE 4

produced only two clusters. These numbers are much smaller than is the number of two-cluster plants found in 1932. On these two plots there were many plants with more than three clusters; in fact, most of the distributions contain more than three; the sample of 1932 contained very few plants with more than three.

ANALYSIS OF TERMINAL UMBELS

TABLE III

DISTRIBUTIONS OF TERMINAL UMBELS FOR PLOTS I AND II

No. of terminal umbels per plant	Frequency or no. of plants	
	Plot I	Plot II
2	7	8
3	294	207
4	185	215
5	26	41
6	...	14
Total	512	485
Mean	3.449	3.682
S.D.	0.612	0.769

There is significance between the means of these distributions; they indicate that the crowded habitat of Plot I was not conducive to the production of as many terminal clusters as the open habitat. On Plot I there were no plants with only one terminal and none with more than five; on Plot II there were none with more than six. Figure 5 presents these distributions.

It is interesting to note that in the first group the means of distributions for plants with at least three terminal inflorescences are:

	Plot I	Plot II
Mean of T =	12.782 pedicels	13.215 — pedicels
Mean of A =	16.972 "	16.888 "
Mean of B =	17.246 "	17.549 "

These averages for both plots satisfy the inequalities:

Mean of T < mean of A < mean of B.

These inequalities seem to indicate that the branch which comes from the stem at the lowest point produces terminal umbels with the greatest number of pedicels. For each plot, averages for branch

terminals A and B are significantly larger than averages for stem terminals; that is, branches on the average produce larger terminal inflorescences than stems do. Frequency polygonals of these distributions appear in Figure 3 and allow the eye to see at once some of the differences between distributions for stem and branch terminals for the sample of 1932 and the two 1934 samples. Polygons

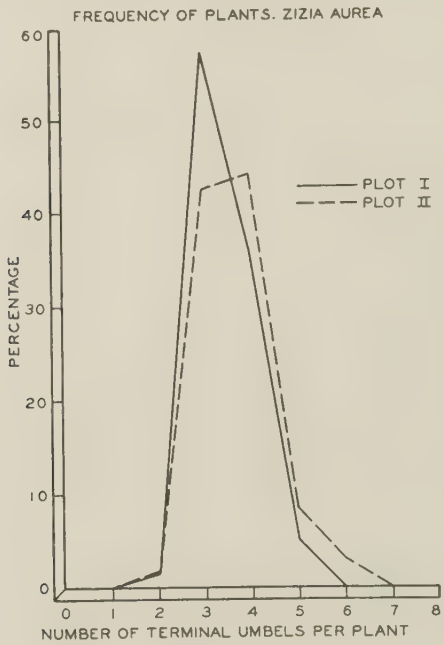


FIGURE 5

on the left represent frequencies for stem terminals; those on the right, for branch terminals. There is very little difference between the means for first and second branch-terminal umbels. From the figure it can be seen that the ranges for distributions for branch terminals are about the same; that the modes are at the same place for the various samples; and that the general shapes of the polygons are about the same; yet in every case the mean for B is a little larger than that for A.

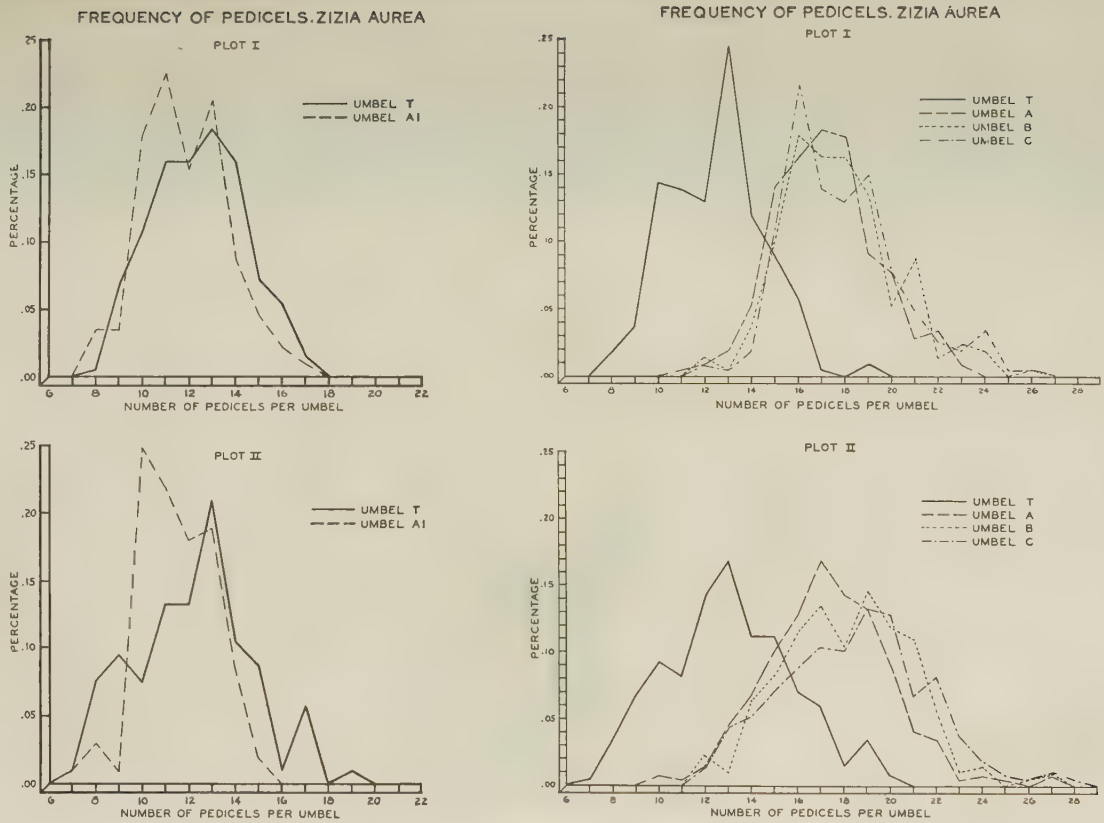

FREQUENCY OF PEDICELS. ZIZIA AUREA
PLOT I
UMBEL T
UMBEL A1
PERCENTAGE
NUMBER OF PEDICELS PER UMBEL
PLOT II
UMBEL T
UMBEL A1
PERCENTAGE
NUMBER OF PEDICELS PER UMBEL
FREQUENCY OF PEDICELS. ZIZIA AUREA
PLOT I
UMBEL T
UMBEL A
UMBEL B
UMBEL C
PERCENTAGE
NUMBER OF PEDICELS PER UMBEL
PLOT II
UMBEL T
UMBEL A
UMBEL B
UMBEL C
PERCENTAGE
NUMBER OF PEDICELS PER UMBEL

FIGURE 6

In Table IV the means of the second group of distributions, which pertain to plants with at least four terminals, are as follows:

	Plot I	Plot II
Mean of T =	12.46 pedicels	13.08 pedicels
Mean of A =	17.15— "	17.33 "
Mean of B =	17.75— "	18.12 "
Mean of C =	17.89 "	18.32 "

These averages satisfy the following inequalities:

Mean of T < mean of A < mean of B < mean of C.

These inequalities again indicate that the branches which come from the stem at points nearest the ground produce terminal clusters with the greatest number of pedicels. Differences between the means for distributions for branch terminals are not significant, yet it appears as though the lower the branch the larger terminal umbel it will have. This is not true for all species in the umbelliferous family. Earlier terminal inflorescences of *Daucus carota* produce on the average more pedicels than do later ones. The first terminal inflorescences are produced by the higher branches, the later ones by the lower branches. The results of the statistical study of *Daucus carota* are to be published later. These distributions are shown graphically in Figure 6; those for axillary terminal clusters are on the right.

There were 26 plants with T, A, B, C, and D clusters on Plot I and 54 on Plot II; their means are as follows:

	Plot I	Plot II
Mean of T =	12.38 pedicels	13.39 pedicels
Mean of A =	16.77 "	17.83 "
Mean of B =	17.38 "	18.44 "
Mean of C =	18.00 "	19.30 "
Mean of D =	17.92 "	19.81 "

For Plot I the mean for D is not greater than the mean for C, yet the former is larger than those for the other terminals. The following inequalities hold for the two plots:

Plot I: Mean of T < mean of A < mean of B < mean of C or D.
Plot II: Mean of T < mean of A < mean of B < mean of C < mean of D.

The groups in Table V include distributions of all terminal inflorescences; their means appear in Table VI.

TABLE IV

DISTRIBUTIONS OF PEDICELS FOR STEM AND BRANCH TERMINAL INFLORESCENCES

No. of pedicels per umbel	Plants with at least three terminal umbels						Plants with at least four terminal umbels							
	Plot I			Plot II			Plot I				Plot II			
	Frequency			Frequency			Frequency				Frequency			
	T	A	B	T	A	B	T	A	B	C	T	A	B	C
6	1	...	...	...	...	...	...	...	...	...	...	...	...	...
7	...	...	1	1	...	...	...	...	...	...	1	...	...	...
8	6	...	...	12	...	...	4	...	...	...	9	...	...	...
9	23	...	...	25	...	1	8	...	...	...	18	...	...	...
10	58	...	1	42	4	1	30	...	...	...	25	2	...	...
11	70	6	4	45	6	3	29	1	...	...	22	1	...	...
12	67	5	12	70	11	14	27	2	3	2	37	4	6	4
13	104	23	14	82	26	17	51	4	1	1	45	12	3	12
14	63	33	35	56	45	32	25	13	8	4	30	18	17	14
15	45	67	54	46	49	51	19	29	21	23	30	27	22	19
16	31	97	89	24	66	61	12	34	37	45	19	34	31	33
17	17	84	77	26	66	58	1	38	34	29	16	45	36	28
18	4	68	62	13	57	44	...	37	34	27	4	38	28	27
19	6	37	61	13	62	63	2	19	28	31	9	36	39	36
20	3	30	26	5	32	46	...	16	11	16	2	24	31	33
21	...	25	32	4	16	37	...	6	18	11	...	11	29	18
22	...	13	11	2	13	19	...	7	3	6	...	9	15	22
23	1	6	11	...	3	4	...	2	5	4	...	1	3	10
24	...	4	5	...	4	8	...	...	4	7	...	2	4	5
25	...	1	1	...	3	2	...	...	...	1	...	1	...	2
26	...	...	2	...	...	2	...	...	1	1	...	...	1	1
27	...	...	1	...	3	2	...	...	...	...	...	2	2	2
28	...	...	...	...	...	1	...	...	...	...	...	...	...	1
Total	499	499	499	466	466	466	208	208	208	208	267	267	267	267
Mean	12.78	16.97	17.25−	13.21	16.89	17.55−	12.46	17.15−	17.75−	17.89	13.08	17.33	18.12	18.32
S. D.	2.36	2.48	2.72	2.81	2.83	2.99	2.05+	2.21	2.44	2.53	2.73	2.67	2.76	3.06

TABLE V

FREQUENCY DISTRIBUTIONS OF PEDICELS FOR ALL TERMINAL UMBELS

No. of pedicels per umbel	Plot I					Plot II					
	Frequency					Frequency					
	T	A	B	C	D	T	A	B	C	D	E
6	1	...	...	...	...	...	...	...	...	...	...
7	...	...	1	...	...	1	...	...	...	...	...
8	6	...	...	...	...	12	...	...	...	...	...
9	23	...	...	...	...	26	...	1	...	...	...
10	60	...	2	...	...	45	4	1	...	...	...
11	71	6	4	...	...	47	6	3	1	...	...
12	68	5	12	2	1	73	12	14	4	...	...
13	104	23	15	1	...	83	29	18	12	...	...
14	65	33	35	4	...	60	45	32	15	1	...
15	48	70	54	23	4	46	52	52	19	5	...
16	33	98	89	47	3	25	67	61	33	4	...
17	19	85	77	28	6	27	67	58	30	6	...
18	4	69	62	29	3	14	58	45	27	6	1
19	6	37	62	33	5	13	63	65	37	7	4
20	3	32	26	17	...	5	33	48	37	6	4
21	...	25	32	10	1	5	16	37	18	5	2
22	...	14	11	7	1	3	13	19	22	6	2
23	1	7	11	4	2	...	3	4	11	5	1
24	...	4	5	7	...	...	4	8	5	3	1
25	...	1	1	1	1	...	3	2	2	1	1
26	...	...	2	1	...	...	...	2	1	...	...
27	...	...	1	...	...	...	3	2	2	3	1
28	...	...	...	...	...	...	...	1	1	...	...
Total	512	509	502	214	27	485	478	473	277	58	17
Mean	12.81	16.99	17.23	17.90	17.96	13.23	16.93	17.57	18.30	19.76	21.12
S.D.	2.36	2.49	2.74	2.51	2.85—	2.84	2.83	2.98	3.07	3.22	2.37

TABLE VI

MEANS OF THE DISTRIBUTIONS OF TERMINAL INFLORESCENCES

Cluster	Plot I		Plot II	
	Av. no. of pedicels	No. of plants	Av. no. of pedicels	No. of plants
T	12.81	512	13.23	485
A	16.99	509	16.93	478
B	17.23	502	17.57	473
C	17.90	214	18.30	277
D	17.96	27	19.76	58
E	....	...	21.12	17

These averages for means satisfy the following inequalities:

Mean of T < mean of A < mean of B < mean of C < mean of D < mean of E.

These inequalities seem to indicate that branch-terminal clusters produce on the average more pedicels the farther the point from which the branch comes from the stem is located below the stem terminal. Lower branches yield clusters which bloom later in the

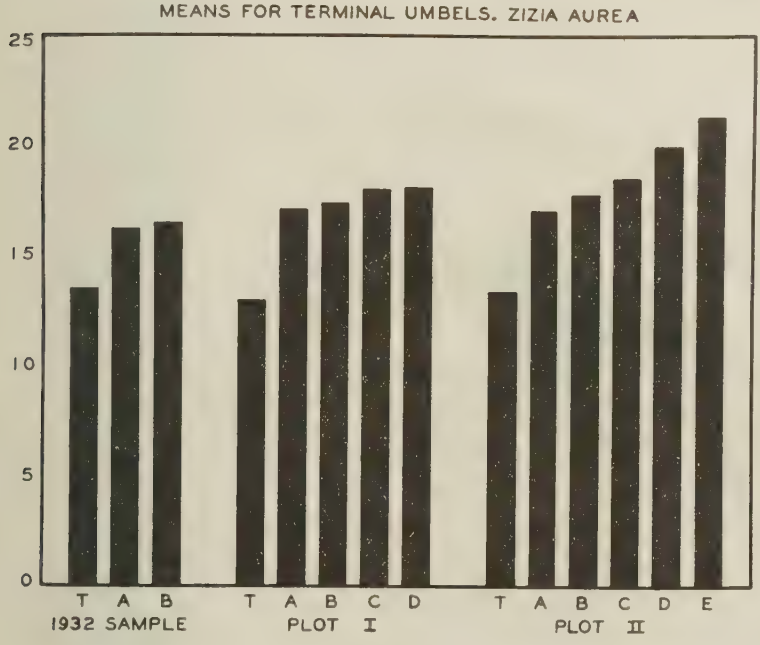


FIGURE 7

season than higher branches. An examination of Figure 7 indicates the successive increases of these means.

The differences between the means for early and late branch terminals are significant. It appears from this study that the later branch terminals produce larger inflorescences than branch terminals which bloom at the beginning of the flowering season. It must be observed in this connection that there are not a great many D and E clusters.

In all groups previously considered the means for stem terminals are significantly smaller than those for branch terminals, and later branch terminals have more rays per umbel than do earlier branch-terminal umbels.

CORRELATION BETWEEN TERMINAL UMBELS

The linear correlation coefficients between the number of pedicels per umbel for various pairs of umbels are found in the following table.

TABLE VII

CORRELATION COEFFICIENTS FOR VARIOUS PAIRS OF TERMINAL UMBELS

Name of cor. coef.	Plot I		Plot II	
	Value	No. of plants	Value	No. of plants
r_{TA}	0.102*	509	0.244†	478
r_{AB}	0.871	499	0.886	466
r_{BC}	0.789	210	0.813	271
r_{CD}	0.872	27	0.790	54
r_{DE}	....	...	0.625+	16

* Standard error = ± .044. † Standard error = ± .043.

Values for r_{TA} indicate that there is very little correlation between stem terminal and first axillary terminal. Values of r_{AB} reveal high correlation between first and second axillary terminals. This suggests that, if the first branch terminal has a small number of pedicels, then the second branch terminal will also have a small number; and if the first branch terminal has a large number, so will the second branch terminal; etc. Values of r_{CD} and r_{DE} indicate high correlation between third and fourth terminals and between fourth and fifth terminals, respectively.

COMPARISON OF TERMINAL FLOWERS

Since there were striking differences between stem- and branch-terminal inflorescences, it was decided to examine the flowers of the two kinds of umbels to determine whether or not there were still other differences. On examining umbellets of stem terminals it was discovered that many of them had imperfect or staminate flowers entirely; the majority had more staminate than perfect

flowers. The following table gives the number of stem-terminal umbels with imperfect, perfect, and a mixture of perfect and imperfect flowers.

TABLE VIII

FREQUENCY OF KINDS OF FLOWERS OF STEM-TERMINAL UMBELS

Description of umbels	Plot I Frequency	Plot II Frequency
Umbels with only staminate flowers.....	147	237
Umbels with the majority of flowers imperfect	307	229
Umbels with the majority of flowers perfect	50	19
Umbels with only perfect flowers.....	5	...
Umbels where there was a doubt	3	...
Total	512	485

This table shows clearly that stem-terminal umbels produce more imperfect flowers than perfect and that there are very few umbels of stem terminals which have only perfect flowers.

In Plate VI, *M*, *N*, and *P* are stem-terminal umbels. Cluster *N* has small pseudo-ovaries, or little knobs, at the ends of the small rays. It did not have a single perfect flower; *M* and *P* had umbellets with perfect flowers and also several without a single perfect flower. In Plate VII, *h* shows imperfect flowers with false ovaries; *k*, perfect flowers with real ovaries. Figures *m*, *n*, *p*, and *q* present top views of imperfect or staminate flowers. In each of these, petals and stamen can be seen; there are no pistils. Figures *r* and *s* enable one to see staminate and perfect flowers. There are no pistils in *r*. Two stigmas can be seen distinctly in *s*. Most of the stem-terminal inflorescences produced imperfect flowers.

This was not true of branch-terminal inflorescences, for all of them produced perfect flowers. In Plate VI, *Q* and *S* are umbels from branch terminals. Branch umbellets contained at least three circular rows of perfect flowers. The flowers have produced fruit. There is always a perfect flower at the center of the umbellet; around this is a row of *imperfect* flowers; around this row are two rows of perfect flowers. The row of imperfect flowers can easily be seen in the plate; it appears in every umbellet shown. With the exception of this row every row in umbellets of branch terminals produces perfect flowers. This row of imperfect flowers also ap-

pears in every stem-terminal umbellet. Apparently this row of imperfect flowers is characteristic of umbellets of this species.

Stem inflorescences bloom first and remain in bloom for a very short time. Stem umbels seem to remain in bloom for a shorter time than any of the other inflorescences.

ANALYSIS OF NONTERMINAL AXILLARY UMBELS

TABLE IX

FREQUENCY DISTRIBUTIONS OF NONTERMINAL UMBELS FOR THE 1934 SAMPLES

The mode of each distribution is two.

No. of nonterminal umbels per plant	Frequency or no. of plants	
	Plot I	Plot II
1	85	42
2	107	45
3	37	25
4	19	20
5	11	10
6	5	4
7	...	2
Total	264	148
Mean	2.16	2.53

The last two tables show that nonterminal umbels are not so important as branch terminals, since there are so many more plants which produce branch terminals than there are which produce nonterminals. Plot II yielded 148 plants with nonterminals against 337 with no nonterminals, whereas Plot I yielded 264 with nonterminals against 248 with no nonterminals. It must be remembered that all the plants with nonterminals also had terminals. Most of the nonterminal inflorescences were found on the first and second branches, and the majority of these were first nonterminals. Plot II had plants with more terminals, while Plot I had plants with more nonterminals. Plot II did not contain as much vegetation as Plot I. The plants on the former plot received much more sunshine than the plants on the latter.

In Figure 8 there are frequency polygons of these two distributions. A glance is sufficient to reveal differences between the two plots.

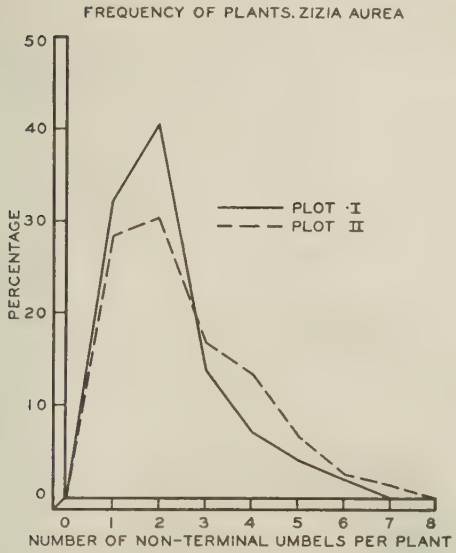


FIGURE 8

COMPARISON OF TERMINAL AND NONTERMINAL AXILLARY CLUSTERS

Frequency distributions for plants with T, A, A1, B, B1, C, and C1 for both plots were found. Their means are given in the table below.

TABLE X

AVERAGE NUMBER OF PEDICELS FOR BRANCH-TERMINAL AND FIRST NONTERMINAL UMBELS

Cluster	Av. no. of pedicels	
	Plot I	Plot II
A	17.35−	16.58
A1	12.35−	11.85
B	18.07	17.25+
B1	13.07	12.00
C	18.28	18.00
C1	13.28	12.43

In every case axillary terminal umbels are significantly larger than the corresponding first nonterminal axillary umbels. Non-

TABLE XI

AVERAGE NUMBER OF PEDICELS FOR BRANCH-TERMINAL AND FIRST NONTERMINAL UMBELS

Cluster	Plot I			Plot II		
	Av. no. of pedicels	No. of plants	Range	Av. no. of pedicels	No. of plants	Range
A	17.21	198	14	16.79	109	15
A1	11.81	198	10	11.49	109	9
B	17.82	199	18	17.46	123	13
B1	12.22	199	11	11.81	123	12
C	18.15+	65	13	18.23	56	13
C1	13.07	65	8	12.67	56	10

terminals A1, B1, and C1 bloom later in the season than branch terminals; in many of them these nonterminals do not appear. Averages for nonterminal clusters from both plots satisfy the following inequalities:

Mean of A1 < mean of B1 < mean of C1.

These inequalities seem to indicate that late first nonterminal umbels are larger than early first nonterminals.

Ranges for distributions for nonterminal umbels are smaller than ranges for distributions for branch terminals, and these show that the items in the former distributions are closer to their means than are the items in the latter. There is less variation in the size of nonterminals than in terminals.

Groups of Table XII give the respective means of terminals and nonterminals. In these cases there are more plants, and results from them should give a better idea of the differences of their means. These are found in Table XI.

The following inequalities are satisfied for the two plots:

Plot I: Mean of A1 < mean of B1 < mean of C1 or of D1;
Plot II: Mean of A1 < mean of B1 < mean of C1 < mean of D1.

These inequalities indicate that on the average the first nonterminal umbels on lower branches produce more pedicels than those on higher branches. The data suggest that later first nonterminal clusters are on the average larger than corresponding

TABLE XII

FREQUENCY DISTRIBUTIONS OF PEDICELS FOR BRANCH-TERMINAL AND FIRST NONTERMINAL UMBELS

No. of pedicels per umbel	Plot I						Plot II					
	Frequency		Frequency		Frequency		Frequency		Frequency		Frequency	
	A	A1	B	B1	C	C1	A	A1	B	B1	C	C1
5	...	...	...	...	...	...	...	...	...	1	...	...
6	...	...	...	...	...	...	...	...	...	...	...	...
7	...	...	...	2	...	...	...	1	...	1	...	...
8	...	7	...	5	...	...	...	4	...	2	...	...
9	...	8	...	5	...	1	...	2	...	9	...	1
10	...	35	1	19	...	4	2	26	...	20	...	1
11	1	44	...	43	...	8	1	24	...	17	...	7
12	2	31	4	37	1	10	5	19	3	26	1	10
13	7	41	3	37	...	15	6	21	3	26	2	10
14	12	17	10	28	2	13	11	10	14	13	2	9
15	30	9	17	17	5	8	12	2	12	3	4	12
16	37	4	38	5	15	6	11	...	20	5	12	2
17	33	2	29	1	8	...	19	...	13	...	5	2
18	26	...	21	...	7	...	12	...	9	...	4	1
19	9	...	29	...	12	...	12	...	17	...	4	...
20	15	...	9	...	2	...	8	...	13	...	4	...
21	9	...	19	...	3	...	3	...	11	...	9	...
22	9	...	6	...	3	...	3	...	6	...	3	...
23	7	...	6	...	2	...	1	...	...	...	4	...
24	1	...	4	...	5	...	3	...	2	...	1	...
25	...	...	...	...	...	...	...	...	...	...	...	...
26	...	...	2	...	...	...	...	...	...	...	...	...
27	...	...	1	...	...	...	...	...	...	...	1	...
28	...	...	...	...	...	...	...	...	...	...	...	1
Total	198	198	199	199	65	65	109	109	123	123	56	56
Mean	17.21	11.81	17.82	12.22	18.15+	13.07	16.79	11.49	16.47	11.81	18.23	12.67
S.D.	2.58	1.83	2.84	2.86	2.79	1.72	2.95−	1.62	2.72	1.94	3.92	2.74

early ones. Bar diagrams in Figure 9 indicate the successive increases from branch to branch.

Again, means for first nonterminal clusters are significantly smaller than means for branch terminals.

Ranges for distributions of nonterminals are much smaller than those of branch terminals. These ranges are given in Table XII.

The ranges and the standard deviations show that the items in distributions for nonterminals are less scattered about their means than are the items in distributions for terminals. Nonterminal umbels are less variable than terminal umbels.

Frequency polygons appear in Figure 10; they enable the eye

to see at once the nature of the distributions of the number of pedicels per umbel of axillary terminals and of axillary first nonterminals. Differences between modes, ranges, and general shapes appear more vividly in an examination of these diagrams.

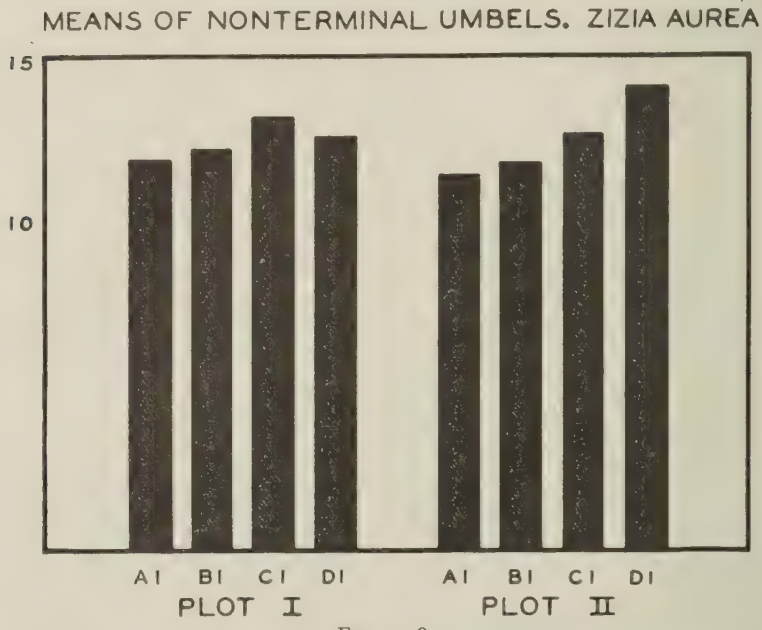


FIGURE 9

CORRELATION BETWEEN AXILLARY TERMINALS AND NONTERMINALS

TABLE XIII

CORRELATION COEFFICIENTS FOR THE VARIOUS PAIRS OF CLUSTERS

Name of cor. coef.	Plot I		Plot II	
	Value	No. of plants	Value	No. of plants
$r_{A\,A1}$	0.405−	198	0.299	109
$r_{B\,B1}$	0.414	199	0.341	123
$r_{C\,C1}$	0.366	65	0.594	56

These values reveal some correlation between branch terminals and first branch nonterminals, but not very much. The correlation coefficient is about 0.4 for Plot I and less than that for Plot II in two of the three cases. This would indicate that the number

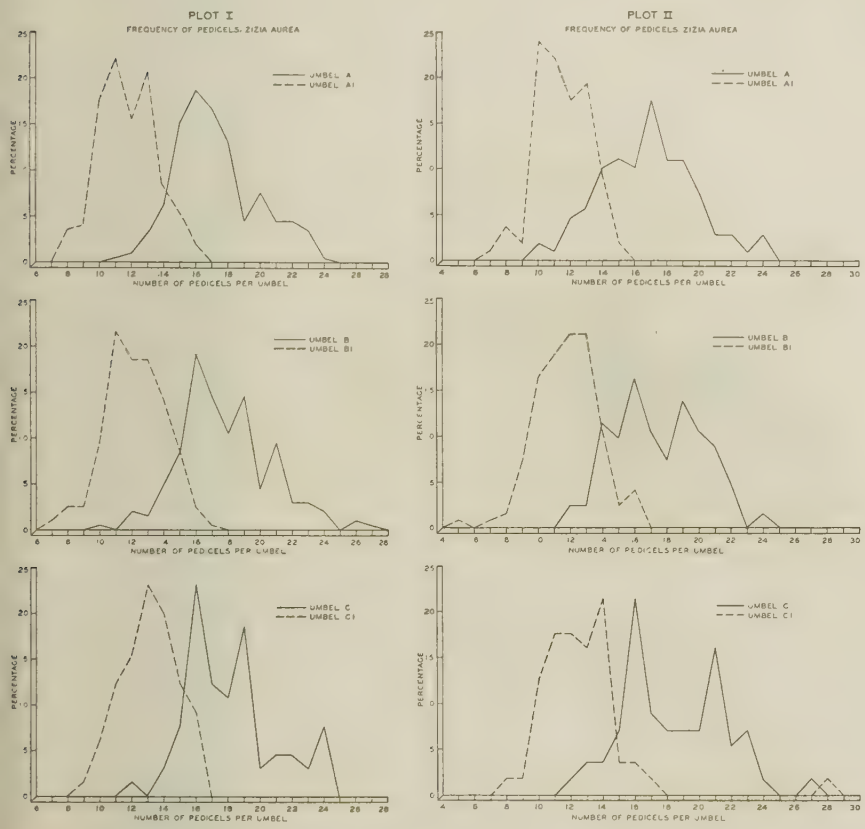


FIGURE 10

of pedicels on a branch first nonterminal umbel was influenced very little by the number that was on the corresponding branch terminal. There were not enough plants with D and D1 to enable one to determine correlation coefficients $r_{D\ D1}$ with any meaning.

TABLE XIV

CORRELATION COEFFICIENTS BETWEEN BRANCH FIRST NONTERMINAL UMBELS

Name of cor. coef.	Plot I		Plot II	
	Value	No. of plants	Value	No. of plants
$r_{A1\,B1}$	0.868	146	0.687	89
$r_{B1\,C1}$	0.718	56	0.593	50

The value of $r_{A1\,B1}$ reveals high correlation between A1 and B1. This suggests that the first nonterminal on the second branch is influenced, in the number of pedicels, by the number of pedicels which the first nonterminal umbel on the first branch had. The size of $r_{B1\,C1}$ for Plot I suggests that first nonterminal umbels on the third branch are influenced, in the number of pedicels, by the number of pedicels which first nonterminals on the second branch had. These values are not so large for Plot II, yet there is a considerable amount of correlation.

To judge from values in Table XIV and those for terminals, there seems to be high correlation between corresponding umbels for successive branches.

Since there was such a small amount of correlation between branch-terminal and nonterminal umbels and very little between stem and branch terminals, the question arose whether there was correlation between stem terminals and branch nonterminals. The following values, which were found from correlation tables, answer this question:

	Plot I	Plot II
$r_{T\,A1}$ =	$0.135 \pm .071$	$0.252 \pm .091$

These values show very little correlation, if any, between T and A1. From values of r_{TA} and $r_{T\,A1}$ it seems as though stem terminals have very little influence, if any, upon inflorescences which bloom after they have bloomed. Differences between distributions of stem-terminal umbels and axillary first nonterminal umbels are shown in Figure 6.

Since there were significant differences between the means for terminal and nonterminal branch clusters, it was natural to ask

TABLE XV

FREQUENCY DISTRIBUTIONS OF PEDICELS FOR PLANTS DESCRIBED BELOW

No. of pedicels per umbel	Plot I						Plot II					
	Plants with only T, A, and B			Plants with T, A, B, and at least one other umbel			Plants with only T, A, and B			Plants with T, A, B, and at least one other umbel		
	Frequency			Frequency			Frequency			Frequency		
	T	A	B	T	A	B	T	A	B	T	A	B
6	1	...	...	...	...	...	...	...	...	...	...	...
7	...	...	...	...	...	1	...	...	...	1	...	...
8	1	...	...	5	...	...	1	...	...	11	...	...
9	5	...	...	18	...	...	5	...	1	20	...	...
10	13	...	1	45	...	...	14	2	1	28	2	...
11	25	5	3	45	1	1	15	5	3	30	1	...
12	21	2	8	46	3	4	24	5	7	46	6	7
13	36	15	10	68	8	4	27	10	10	55	16	7
14	18	13	19	45	20	16	20	18	8	36	27	24
15	16	21	21	29	46	33	13	17	26	33	32	25
16	15	35	31	16	62	58	5	26	24	19	40	37
17	14	28	23	3	56	54	6	16	17	20	50	41
18	3	19	15	1	49	47	9	16	14	4	41	30
19	4	14	20	2	23	41	3	20	15	10	42	48
20	3	8	10	...	22	16	3	6	12	2	26	34
21	...	10	7	...	15	25	4	4	6	...	12	31
22	...	3	2	...	10	9	2	3	2	...	10	17
23	1	...	4	...	6	7	...	1	1	...	2	3
24	...	2	1	...	2	4	...	...	1	...	4	7
25	...	1	1	...	...	...	...	2	2	...	1	...
26	...	...	...	...	...	2	...	...	1	...	...	1
27	...	...	...	...	...	1	...	...	...	...	3	2
28	...	...	...	...	...	...	...	...	...	...	...	1
Total	176	176	176	323	323	323	151	151	151	315	315	315
Mean	13.45—	16.61	16.59	12.42	17.17	17.61	13.65—	16.36	16.63	13.01	17.14	17.99
S.D.	2.68	2.64	2.80	2.07	2.47	2.61	3.00	2.83	3.00	2.68	2.79	3.07

whether there were differences in the flowers produced by them. On examining the flowers of these clusters it was found that there were no differences. That is, both produced perfect flowers, with the exception of the circular row of imperfect flowers on each umbellet, which was mentioned above. The only umbels which produced staminate flowers, other than those in the row noted above, were stem umbels.

COMPARISON OF PLANTS WITH ONLY TERMINAL UMBELS AND PLANTS WITH OTHER UMBELS

On Plot I there were 176 plants with only three terminal umbels, T, A, and B, and 323 with T, A, B, and at least one other umbel. Plot II contained 151 with only T, A, and B, and 315 with T, A, B, and at least one other umbel. The means for these distributions and the distributions themselves are given in Table XV.

TABLE XVI

AVERAGE NUMBER OF PEDICELS FOR TERMINAL INFLORESCENCES

Plot	Cluster	Plants with only T, A, and B	Plants with T, A, B, and at least one other cluster
		Av. no. of pedicels	Av. no. of pedicels
I	T	13.45−	12.42
	A	16.61	17.17
	B	16.59	17.61
II	T	13.65−	13.01
	A	16.36	17.14
	B	16.63	17.99

There are significant differences (1) between the means of distributions of stem-terminal umbels, of plants with only three terminals, and of plants with three terminals and at least one other umbel for both plots; (2) between the means for clusters B for both plots; and (3) between the means for cluster A for Plot II.

On examining the table it is seen that on the average stem-terminal umbels are larger for plants with three terminal umbels and no more of any kind than for plants with three terminal umbels and at least one other umbel. For branch terminals the situation was the opposite of this. On the average, larger branch terminals were found on plants which had at least four umbels, three of which were T, A, and B. It seems natural to think that plants with few umbels would produce umbels with more pedicels, since there was more food for each umbel, but this was not true for the first two branch terminals A and B.

SUMMARY

This statistical study of *Zizia aurea* has shown that:

1. Stem-terminal inflorescences differ significantly from axillary terminal inflorescences; that is, stem inflorescences have fewer pedicels than axillary terminals.

2. Stem-terminal clusters produce imperfect flowers, whereas axillary clusters do not, except for one row of flowers.

3. There is very little correlation between the number of pedicels per umbel on stem and branch umbels.

4. Plants with fewer than four umbels, all of which are terminals, produce stem umbels with more rays than other plants do.

5. Most of the plants have only two axillary terminal inflorescences.

6. Axillary terminal clusters blooming at the first of the season have fewer pedicels than those blooming at the close of the season; and the lower the point from which the branch grows from the stem, the more pedicels its terminal will have.

7. There is high correlation between the number of rays per umbel on successive branch-terminal umbels.

8. On every umbellet there is one row of imperfect flowers; this row is around the center flower.

9. Terminal and nonterminal axillary inflorescences differ significantly in the average number of pedicels; terminal ones have the larger number.

10. There is very little correlation between the number of rays per cluster on terminal and nonterminal clusters on the same branch.

11. There is high correlation between the number of pedicels per umbel on corresponding nonterminal umbels on successive branches.

12. There are fewer nonterminal umbels than terminals; most of the nonterminals are on the first two branches; and many times there are no nonterminals.

13. The number of pedicels on stem and axillary inflorescences varies with environment.

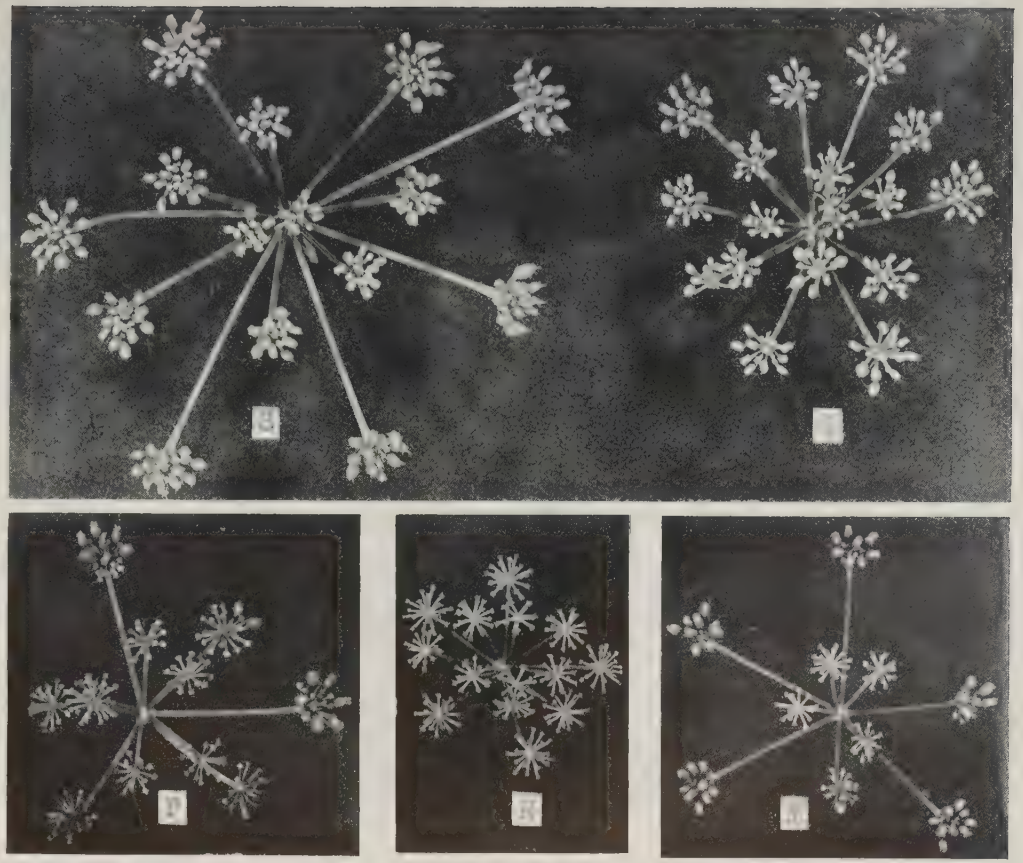
14. Early blooming first nonterminal clusters have fewer rays than those blooming later.

15. The Pearson Type IV curve fits all distributions of the 1932 sample, but does not fit all distributions of the 1934 samples.

Bimodal, multimodal, and complicated distributions often arise because the sampler is not careful to separate data pertaining to flowers at different positions on the plants; for example, the number of pedicels per stem terminal should not be mixed with the number per branch umbel. This study should serve as a caution to the reader who desires to make statistical investigations concerning flowers to keep a close check on the positions at which the flowers grow.

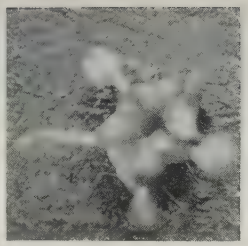
University of Michigan

Zizia aurea

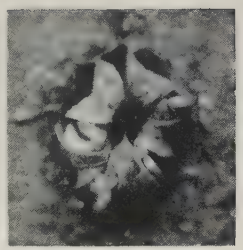


Zizia aurea

PLATE VII



m



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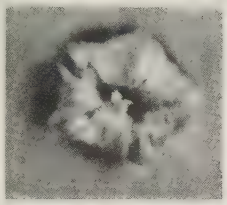

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Zizia aurea

THE RESPIRATORY QUOTIENT AND ITS INDICATION OF WHAT CHEMICAL ACTIVITIES TAKE PLACE IN TOMATO FRUITS *

FELIX G. GUSTAFSON

FOR a number of years the author has been studying the respiration of tomato fruits. In the earlier of these experiments only the CO_2 output was determined, but in the more recent ones both the CO_2 output and the O_2 consumption have been determined. As will be shown in another report, the two may differ widely. And who is to say that one is more truly a measure of the respiration than is the other? In order to get a clearer picture of what is happening in the organism one should, whenever possible, determine both the CO_2 production and the O_2 consumption. In this paper there will be considered only the ratio between the CO_2 production and the O_2 consumption as influenced by the stage of development of the fruit, lapse of time in darkness since picking, and by the oxygen and the CO_2 concentration of the surrounding atmosphere.

These experiments were conducted over a period of several years, during all seasons of the year. The plants were grown in the greenhouse and out of doors, so that the results can be considered representative of the variety used, namely, John Baer, under several growing conditions.

The fruits were picked from the greenhouse or the field as needed, and as soon as they could be brought to the laboratory they were placed in the dark, constant-temperature room where the experiment was to be conducted. The time interval between placing the fruits in the dark room and first sampling varied somewhat. If the fruits were taken directly from the warm greenhouse into the warm-temperature room, a period of about two to three hours

* Papers from the Department of Botany of the University of Michigan, No. 533.

was allowed to elapse. When the fruits from the warm greenhouse were placed in the cold room or when they were brought from the field in the fall into the warm room, a five-hour interval was allowed to bring the fruits into equilibrium with the temperature of the experimental room.

During the experiment the fruits whose respiration was studied were enclosed in glass bottles sealed with rubber stoppers. The size of the bottles used varied from about four to six liters. During the experiments the air in the bottle was continuously stirred by a device made for the purpose. In numerous experiments only one fruit was used, while in others many were employed. The large volume of air and few fruits were employed to insure an oxygen concentration near that of the normal atmosphere.

Samples of air were drawn out of the bottles into a gas-sampler having a capacity of 25 c. c. The gas analyses were made with a Henderson-Haldane pipette. Details of analysis, sampling, etc., may be obtained from a paper on "Microbic Respiration," by Novy, Rochm, and Soule (6). At the beginning of each experiment and a few minutes after the bottle had been closed a sample of air was drawn from the bottle and analyzed. This procedure gave much more constant results than when no initial analysis was made because, as had been discovered from a few preliminary analyses, the laboratory air was not constant from day to day, especially so far as the CO_2 content was concerned.

The experiments were carried out at two temperature ranges. The lower temperature varied from 15 to 18° C.; the higher, from 30 to 33° C. This does not mean that there was a variation of three degrees in a single experiment, but that some experiments were carried out at a temperature of 15 to 17°, others from 16 to 18°, etc. The temperature fluctuated about two degrees in the lower temperature and less than one degree at the higher temperature. The reason for choosing two temperature ranges was that Gerber (1) in his extensive work on respiration in fruits found that in many fruits acids are respired at a temperature of 30° C. or above (except malic acid which, he states, is utilizable at lower temperatures), whereas acids as a rule are not used at lower temperatures. Sando (7) states that, according to the literature, the acids citric, malic, tartaric, benzoic, formic, oxalic, salicylic, and succinic have at some time or other been found in tomato fruits, but the pre-

TABLE I

Relation Between the Respiratory Quotient and the State of Development of the Fruits at Different Temperatures

Temperature	15–18° C.				30–33° C.			
Condition of fruit	Red ripe	Red-orange Orange-red	Green-yellow-pink	Green	Red ripe	Red-orange Orange	Yellow-green	Green
Average R.Q.....	0.97	0.96	0.72	0.78	1.03	0.96	0.99	0.98
Range of R.Q....	0.83–1.03	0.83–1.00	0.68–0.79	0.55–1.02	1.03–1.06	0.74–1.05	0.95–1.03	0.83–1.23
No. of Experiment	4	4	5	19	4	5	2	12
No. of fruits.....	25	7	24	405	10	7	12	59
Diameter of fruits in cm.....				1.06–6.88				4.00–6.24

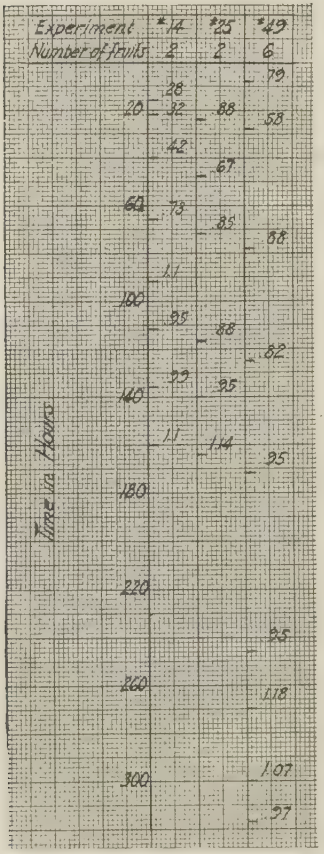
ponderance of opinion seems to be that the chief acid in the tomato is citric. If the acid present is mainly citric and the findings of Gerber are correct, the respiratory quotient (R.Q.) should be above unity at a temperature of 30° or above, while it may be below one at a lower temperature, provided the acid concentration is fairly high. So far as the writer knows, the analyses mentioned above were made on ripe or semiripe fruits. In the present investigation the fruits varied from green ones, only 1.06 cm. in diameter, to fully mature or even overripe fruits. Therefore we cannot depend too much upon previous experiments.

In tomatoes there are no fats, and fat metabolism can therefore be excluded. In plants, protein is very seldom used in respiratory activities, unless more readily available material is lacking. It seems safe to assume that the respirable material in the tomato fruit is composed only of acids and sugars. Sando shows that there is quite a fluctuation in acid and sugar content during the period of development of the fruit. Sugars give an R.Q. of unity. Then under conditions in which we can exclude fermentation any fluctuation of the R.Q. from unity is due to acid metabolism.

The original purpose of this series of experiments was to determine the R.Q. in tomato fruits at different stages of development. Some sixty odd experiments have been performed, some of which lasted for only a few hours or long enough to take two

samples of gas at an interval of several hours; others were continued for about three weeks. In the long experiments the fruits were taken out of the bottles a number of times and the air replenished.

The R.Q., as obtained from these experiments at the two temperatures, before any secondary temperature effects were produced, has been called the initial R.Q. These are presented in Table I.



At a temperature of 15 to 18° C. the ripe and the near ripe fruits have an R.Q. near unity, whereas the green of all ages and also the fruits which are in the early stages of ripening, as shown by the color ranging from light green to pink, have an R.Q. very much below unity.

At the higher temperature there is no appreciable difference in the R.Q. at different stages of development. This statement must be qualified, because no really young fruits were used; the smallest fruits were 4 cm. in diameter, and at that size they must have been several weeks old. There is, then, no evidence of a large quantity of acid being utilized in respiration at the temperature 30 to 33° C. This is contrary to Gerber's findings, but he did not use the tomato.

Fig. 11. Change in R.Q. during the ripening process of tomato fruits. The horizontal lines in each column denote the time elapsed since the first sample was taken, and the figure opposite each line is the R.Q. which is the average for the interval since the last sample was taken. In all these experiments the fruits were green at the beginning; in Experiments 14 and 25 the fruits were yellow-pink, and in 49 they were ripe at the end of the experiment. Experiments 14 and 49 were conducted at 15-18° C, while 25 was conducted at 30-33° C. In the first two the O_2 concentration never went below 19 per cent, but in the last experiment the O_2 concentration at the end was 11.4 per cent

Three experiments were conducted, two at 15 to 18° C. and one at 30 to 33° C., in which the R.Q. was obtained on the same fruits during the process of ripening. In all three the fruits were green when collected, but during the progress of the experiment they were ripening, as shown by the change in color. At the end the fruits of two experiments were pink-orange while those of the third, which lasted longer, were ripe. During the yellowing process the R.Q. rose until a value above one was reached (Fig. 11). In Experiment 49, in which the fruits were ripe at the end, there was a decrease during the later stage. The change in R.Q. from a value below unity to one above unity in the ripening process, as shown

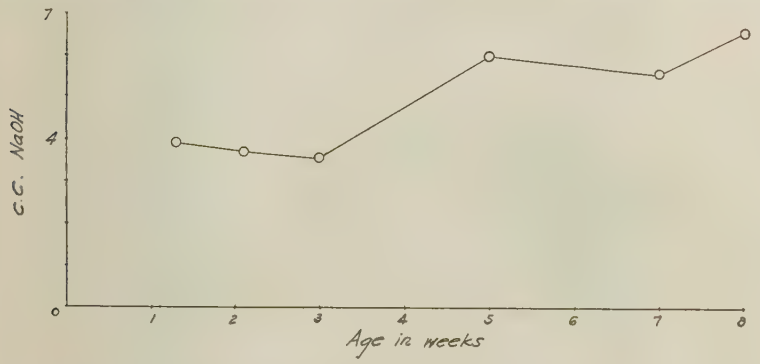


Fig. 12. Changes in total acidity concentrations during the development of tomato fruits. Each point on the curve is the average of fifty fruits grown in the field. Reproduced from a paper by the author (2)

in these three experiments, strikingly corroborates what was brought out as a composite picture from numerous experiments with fruits of different ages and condition of ripeness (Table I). Kidd (5) has found that in the apple, up to the climactic period, when there is an increase in respiration activity, the R.Q. is below one, but at this period there is a change from less than unity to more than unity.

The change from a low to a high R.Q. during the period of ripening can be explained on the basis of acid production and utilization. In a former paper (2) the writer has shown that the total acidity increases until the fruits are five to six weeks old, which corresponds to the time at which the color change begins to take

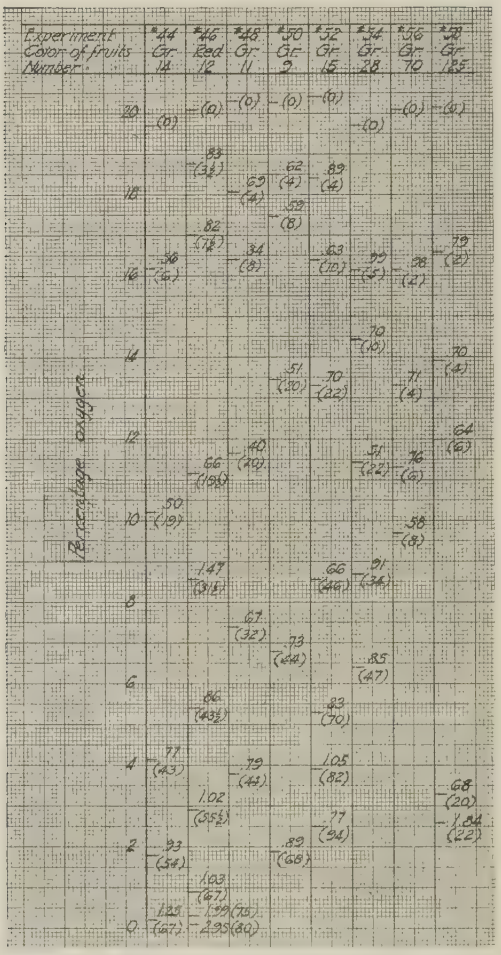


FIG. 13. R.Q. at different oxygen concentrations at 15–18° C. The short horizontal lines in each column denote the O_2 concentration at which the samples were taken. The figure opposite each line is the R.Q. which is the average for the interval since the last sample was taken. The figures in the brackets below each R.Q. value represent the time in hours since the initial sample was taken, which is usually considered the beginning of an experiment

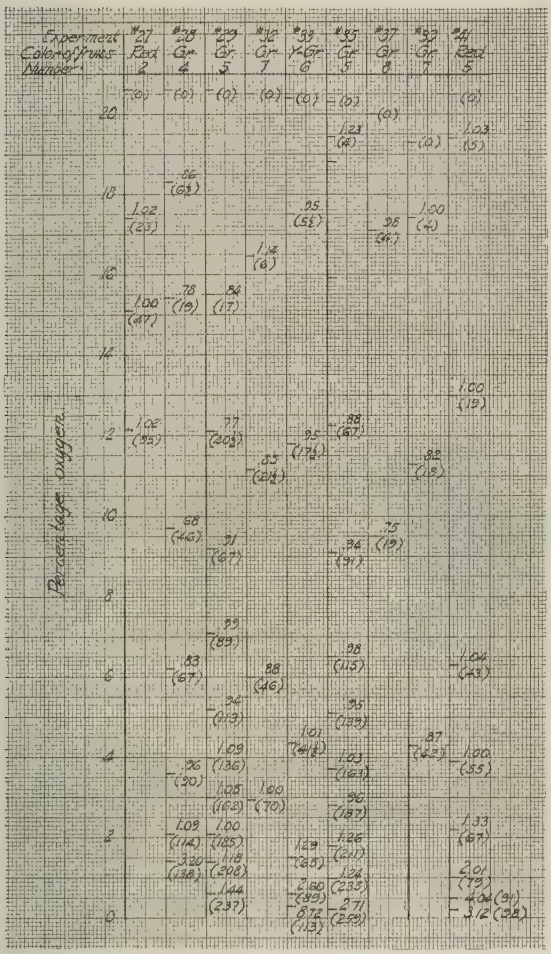


FIG. 14. R.Q. at different O_2 concentrations at 30–33° C. Other data are as in Figure 13

place. This increase is followed by a slight decrease in acidity. Figure 12 is reproduced from the former paper to show these acid changes. The large acid production gives a low R.Q.; and as the acid is utilized during the ripening the R.Q. rises, which is in accordance with the experiments on acid content of tomatoes already cited. In a paper on alcohol and acetaldehyde production by tomatoes it was shown that a small quantity of alcohol is produced by ripening fruits even when they are on the vines (3). This increases the ratio of CO_2/O_2. The acid utilization and the slight anaërobic production of CO_2 do undoubtedly account for the high R.Q. found in the early stages of ripening, while in the later stages the R.Q. would decrease if there is acid production as shown by the fruits in Figure 12.

Experiments on the effect of oxygen tension in the R.Q. will next be presented. At a temperature of 15 to 18° C. the O_2 concentration does not affect the R.Q. until it gets down to about 2 per cent or even less (Fig. 13). This statement may seem contrary to the facts as illustrated by Experiments 44, 48, and 50, where there is an increase in R.Q. in O_2 concentration as high as 4, 7.5, and 6.8, respectively, but, as will be shown later, these increases are due to changes occurring during the first forty hours in the dark, and will occur even when O_2 concentration is very high. The high R.Q. in Experiment 46 occurring at a concentration of 8.62 per cent cannot be accounted for. One might almost state that, until the O_2 concentration becomes as low as one half of one per cent, there is no real effect, as shown by Experiments 44 and 46. In Experiment 58 the R.Q. becomes very large at 2.6, but this can be explained on the basis of the very large number of vigorously respiring fruits, which would probably decrease the O_2 tension around the fruits even though the air was circulated in the bottle.

In Figure 14 are presented data for experiments conducted at a temperature from 30 to 33° C. After a careful perusal of this figure it becomes evident that here, too, there is no definite effect until the O_2 concentration has decreased to around 2 per cent. An R.Q. of one cannot be attributed to the effect of oxygen, because in many experiments this and higher values may be obtained in an O_2 concentration very high, even near that of normal air, as illustrated by Experiments 27, 32, 35, 39, and 41. This high R.Q. value is then followed by lower ones, and only when

the O_2 concentration is decreased to 2 or less will there be a rapid and continuous increase, as shown by Experiments 28, 29, 33, 35, and 41. The R.Q. reached at 30 to 33° C. is very much greater than that at similar O_2 concentrations at the temperature 15 to 18° C. This is to be expected with the much greater rate of respiration.

The high R.Q. at low O_2 tensions is no doubt due to anaërobic respiration setting in, when there is no longer sufficient oxygen left in the atmosphere. For a while both the aërobic and the anaërobic processes go on side by side, with the anaërobic gradually increasing in importance as the aërobic decreases in magnitude.

At the same time that the oxygen was decreasing in these experiments the CO_2 concentration was increasing; and, although in the preceding discussion only oxygen has been mentioned, one must bear in mind that the increase in CO_2 may also influence the respiratory quotient.

Therefore the effect of the increase in CO_2 concentration upon the R.Q. has also been considered. Figure 15 shows the relation between R.Q. and CO_2 concentration at 15 to 18° C. In only three experiments was the R.Q. above one at the end, and in these the CO_2 concentration was 13.8, 15, and 20.2 per cent, quite a wide variation. In contrast to these data are Experiment 50, in which the R.Q. was 0.89 though the CO_2 concentration was 13.6, and Experiment 52, in which the respiratory quotient was 0.77 although the CO_2 concentration was 14.3, or 0.5 per cent higher than in Experiment 58. The three experiments with the high R.Q. have not in common a high CO_2 concentration, but they do have in common a low O_2 concentration. This is especially true for Experiments 44 and 46. In Experiment 58, as has already been explained, the fruits were very crowded, some resting on top of others, and this, in spite of air circulation, probably produced a lack of oxygen in the vicinity of some of the fruits.

Figure 16 is concerned with the R.Q. and the CO_2 concentration at 30 to 33° C. In Experiments 27 and 41 (with ripe fruits) there was no appreciable change until in Experiment 41 the CO_2 concentration had reached 19.7 per cent, when the R.Q. rose to 1.33. But the O_2 concentration had reached its critical value of 2.2, which might account for this high R.Q. In the remaining seven experiments four have an R.Q. above one. Of these four, Experiment 28 has an R.Q. higher than one at 15.9 per cent CO_2; Ex-

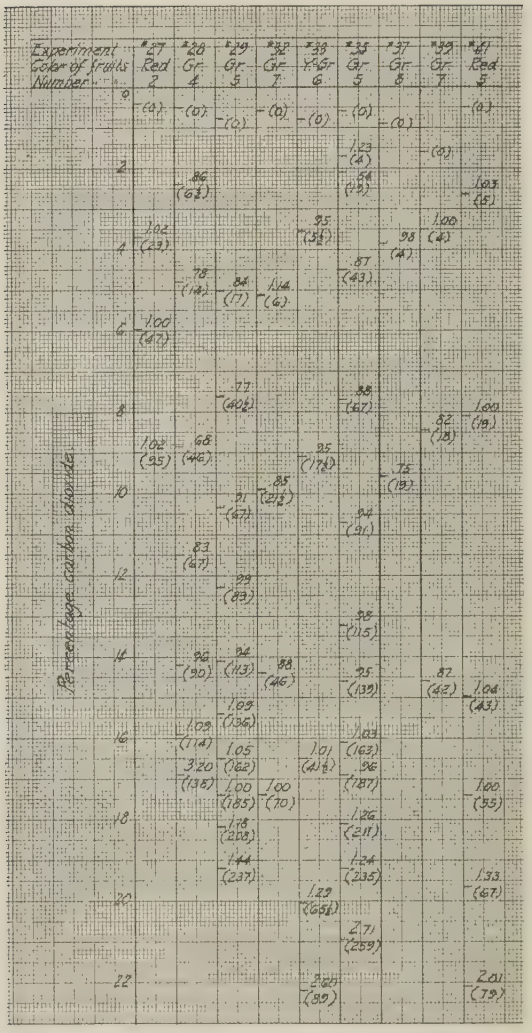
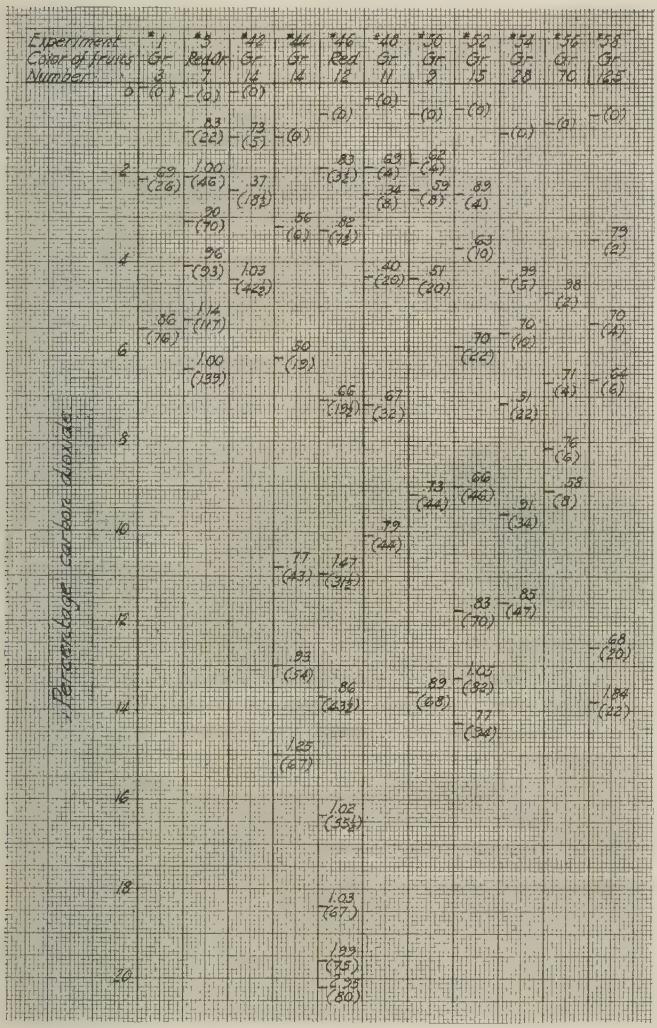


FIG. 15. R.Q. at different CO_2 concentrations at 15-18° C. The short horizontal lines in each column represent the CO_2 concentration at which the sample was taken. Numbers within brackets represent the time since the beginning of the experiment


Experiment
Color of fruits
Number
Gr.
Red
Gr.
Gr.
Red
Gr.
Gr.
Gr.

periment 29 shows the first effect at 15.5, but the value drops to one at 17.3, to rise finally at 18.2. In Experiment 33 the first definite effect is at 20.0 and in Experiment 35, 18.0 per cent CO_2 is the concentration at which the R.Q. is above one. When the R.Q. was definitely above one in the preceding experiments, the respective O_2 concentrations were: in No. 28, 2 per cent; in No. 29, 1.6 per cent; in No. 33, 1.5 per cent; and in No. 55, 1.86 per cent. The CO_2 concentrations at which one can be certain that the R.Q. is not merely fluctuating range from 15.9 to 20, but at all these critical periods the O_2 concentration was very much the same, 1.5 to 2.0 per cent.

The writer is not interested in attempting to demonstrate that the CO_2 concentration does not influence the respiratory quotient, but from a critical examination of the data there is nothing which would justify one in drawing the conclusion that there is an influence of the CO_2 concentration upon the respiratory quotient. The CO_2 concentration at which the R.Q. has become greater than unity varies greatly in the different experiments, but the O_2 concentration is always about 2, or less. The fact that the R.Q. is not influenced by CO_2 concentrations as found in these experiments is in agreement with Kidd's work on germinating white mustard seeds (4). He states that CO_2 concentration of 10 per cent had no influence on the R.Q., but a 20 per cent concentration had a slight effect. A 10 per cent CO_2 concentration depressed the R.Q. in green peas, but a 25 per cent concentration had no further influence on the R.Q.

Many experiments were run for only a day or two to determine whether there were any changes in R.Q. over a short period in darkness at the two temperatures employed, when the oxygen concentration remained quite high, very definitely above the concentration where it affects the R.Q.

In both temperatures there is no noticeable change in R.Q. during a period of two days in the ripe or nearly ripe orange-red fruits. In the green and the slightly colored fruits there is a striking change. Figure 17 gives the data for green fruits at 15 to 18° C. There is unquestionably a decisive drop in the R.Q. during the first few hours in the dark. This period of falling R.Q. may last twenty to thirty hours. The only explanation which can logically be offered for this low production of CO_2 accompanied by a high O_2 consumption is that organic acids high in oxygen are being

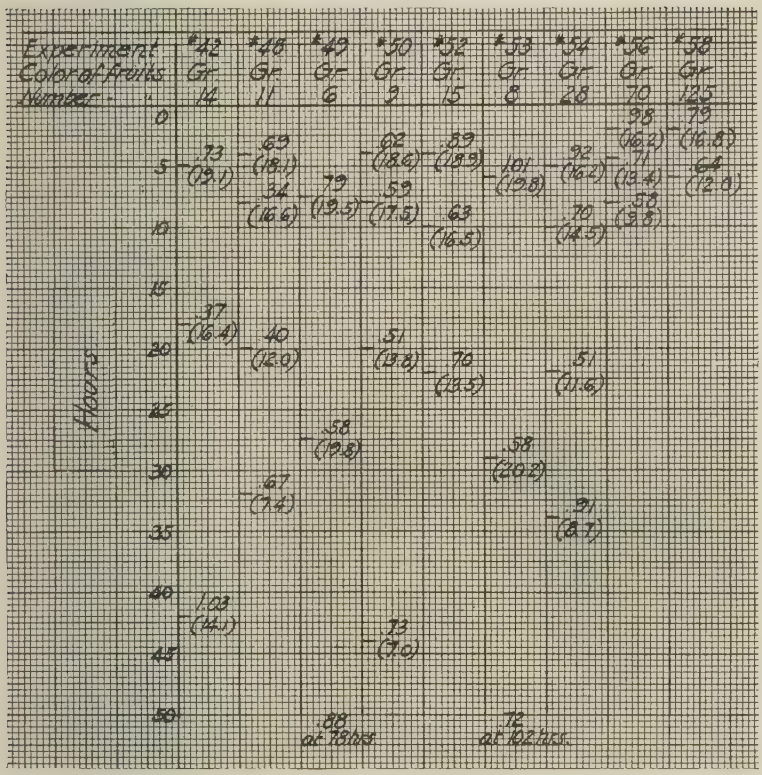


FIG. 17. Change in value of R.Q. with lapse of time at 15–18° C. This figure shows that as the fruits remain in the dark the R.Q. decreases and later increases. The period of decrease may last only a few hours or over twenty hours. The numbers inside the brackets below the R.Q. values denote the O_2 concentration at which the gas sample was taken

produced. The average R.Q. for twenty experiments with green fruits of varying sizes at the temperature 15 to 18° C. is 0.78, and the range is from 0.55 to 1.02. If citric is the acid formed, one molecule of sugar would have to be used in acid formation for every molecule that was used in respiration to give this ratio:

$$C_6H_{12}O_6 + 1\tfrac{1}{2}O_2 = C_6H_8O_7 + 2H_2O$$
$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$$

According to these equations, for every six molecules of CO_2 produced seven and one-half molecules of O_2 are consumed. During the early part of these experiments the R.Q. decreases. This could be accounted for by assuming an increase in the number of molecules of sugar used in acid production, but from a few analyses of total acidity it is known that there is very little if any increase in acidity during the first twenty-four hours of an experiment. However, since there is an actual decrease in CO_2 production, the proportion of sugar used in acid production could be increased without increasing the total acidity very much. Four sugar molecules for acid to one for CO_2 would give an R.Q. of 0.5. Other acids besides citric may be formed to give low values for the R.Q. Thus the R.Q. would be 0.67 if malic acid is formed according to the equation:

$$C_6H_{12}O_6 + 3O_2 = C_4H_6O_5 + 2CO_2 + 3H_2O.$$

Or the R.Q. would be 0.57 with tartaric acid formation:

$$2C_6H_{12}O_6 + 7O_2 = 2C_4H_6O_6 + 4CO_2 + 6H_2O.$$

This assumes that the formation of malic and tartaric acids is part of the respiratory process, which may or may not be true.

With the present information it is pure speculation to attempt to state what acid or acids are formed. Attempts ought to be made to relate the carbohydrate decrease to the CO_2 produced, and from this one might arrive at a more satisfactory conclusion.

The decrease in R.Q. is always followed by an increase, frequently up to the initial value. During this period of rise the CO_2 output usually continues to fall. The acids which were formed during the early starvation period are being used up, or perhaps the ratio between acid formation and CO_2 production goes back to the original value. The latter alternative is more likely, because in experiments on total acidity determinations the acid concentration is found to be greater after forty-eight hours than it was at twenty-four hours. This suggests the formation first of an acid (or acids) of high oxygen content followed by the formation of other acids either having a lower oxygen content or using in their formation less oxygen in proportion to the CO_2 formed.

At the higher temperature of 30 to 33° C. the performance of the green fruits is not consistent. In some fruits the R.Q. increases

during twenty-four to forty-eight hours, but in others there is a decrease. Perhaps not enough data are available at the present time.

These experiments bring out very interesting fluctuations in the respiratory quotient. One of the most striking results is the difference at the two temperatures. At the higher temperature the R.Q. is not nearly so low as in the corresponding experiments at the lower temperature. At the lower temperature the fluctuation is very large during a short period, and also there is the very great difference in the fruits at different stages of development. This difference again shows what has so frequently been pointed out in recent years, namely, that the temperature influences the metabolic processes not only quantitatively but also qualitatively.

SUMMARY

1. At 15 to 18° C. green and partly ripe fruits have an R.Q. considerably below one, i.e. they are producing acid. The ripe or near ripe fruits have an R.Q. very near one, in some experiments a little below and in others a little above.

2. At 30 to 33° C. all the fruits studied had an R.Q. near one.

3. During the ripening process the R.Q. changes from a low value to a value considerably above one.

4. Decreasing the oxygen concentration has no effect upon the R.Q. until a value of about 2 per cent is reached. The results at the two temperatures are essentially the same.

5. Within the range of these experiments (0.08 to 20.0 per cent) the CO_2 concentration does not influence the R.Q.

6. At 15 to 18° C. there is quite a dip in the R.Q. during the first few hours in the dark, usually lasting up to 20–30 hours; after this time the R.Q. rises. This is true only for green and slightly colored fruits. The ripe fruits do not show this fall and rise in R.Q.

7. The results at 30 to 33° C. were variable, and no definite conclusions as to an initial decrease in R.Q. can be drawn from them. In general the R.Q. remains at or near unity.

University of Michigan

BIBLIOGRAPHY

1. Gerber, C. 1896. Recherches sur la maturation des fruits charnus. Ann. Sci. Nat. Bot., Series VIII, 4: 1–279.

2. Gustafson, F. G. 1928. Growth Studies on Fruits. Chemical Analyses of Tomato Fruits. Pap. Mich. Acad. Sci., Arts and Letters, 8 (1927): 121–127.

3. —— 1934. Production of Alcohol and Acetaldehyde by Tomatoes. Plant Physiol., 9: 359–367.

4. Kidd, F. 1916. The Controlling Influence of CO_2. III. The Retarding Effect of CO_2 upon Respiration. Proc. Roy. Soc., B 89: 136–156.

5. —— 1929. Report of the Food Investigation Board for the Year 1928, London. Page 33.

6. Novy, F. G., Roehm, H. R., and Soule, M. H. 1925. Microbic Respiration. I. The Compensation Manometer and Other Means for the Study of Microbic Respiration. Journ. Infect. Dis., 36: 109–167.

7. Sando, C. E. 1920. The Process of Ripening in the Tomato. Considered Especially from the Commercial Standpoint. U. S. Dept. Agric., Bull. 859.

LICHENS FROM THE ALEUTIAN ISLANDS AND THE ALASKA PENINSULA *

JOYCE HEDRICK

THE specimens upon which this report is based were collected by W. J. Eyerdam during the summer of 1932. Collections were made on Atka, Amlia, Carlisle, Unalaska, and Unimak of the Aleutian Islands, at King Cove along the coast of the Alaska Peninsula, on Kodiak and Sitkalidak islands, and at Seldovia on the coast of the Kenai Peninsula.

Clara E. Cummings, in *Lichens of Alaska* (1910), reports a number of species from this region, as does R. Heber Howe, Jr., in "Some Alaskan Lichens" (*Bot. Gaz.*, 56 : 496–500. 1913.). The following list of 46 species and 16 varieties and forms contains 6 species and 8 varieties and forms not reported by these writers. Of these 1 species has not previously been described and 1 species and 2 forms apparently have not been reported for North America.

Two specimens of crustose forms were identified by Dr. A. H. Magnusson, one of which proved to be a new species. The description and comments furnished by him have been included here with slight modifications. Several varieties and forms of Cladonia were identified by Dr. Henri Sandstede and a few species of Cladonia and Stereocaulon by J. L. Lowe.

The writer wishes to thank Dr. E. B. Mains, who made the photographs and gave advice in the preparation of the manuscript.

List of Species

Sphaerophorus coralloides Pers. (Pl. VIII, Fig. 1). — Seemingly very common and mixed with other species on the ground; Unalaska Island, Amlia Island, Atka Island.

Sphaerophorus fragilis (L.) Pers. — Not so common as the preceding species; Unalaska Island, Amlia Island, Kodiak Island.

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 535.

Psoroma hypnorum (Hoffm.) S. Gray. — Atka Island.

Sticta pulmonaria Bir. var. linita (Ach.) Tuck. — Unimak Island.

Sticta quercizans Ach. — Unalaska Island.

Solorina crocea (L.) Ach. — Common and conspicuous; Unimak Island, Carlisle Island, Unalaska Island, Alaska Pen.

Nephroma arcticum (L.) Torss. — Unimak Island, Alaska Pen.

Peltigera aphthosa (L.) Willd. — Unalaska Island, Atka Island.

Peltigera canina (L.) Willd. var. membranacea Ach. — Rather common; Unalaska Island, Unimak Island, Atka Island. None of the specimens appeared to be the species proper, which is reported by both Cummings and Howe.

Peltigera canina (L.) Willd. var. sorediata (Schaer.) Fink. — Sitkalidak Island.

Peltigera malacea (Ach.) Funck. — Kodiak Island. Apparently the first report for Alaska.

Peltigera scutata (Dicks.) Duby. — Alaska Pen. Apparently the first report for Alaska.

Lecidea albocaerulescens (Wulf.) Ach. var. flavocaerulescens (Horn.) Schaer. — Quite common and showing the characteristic iron-red coloring of the thallus; Atka Island, Unalaska Island, Amlia Island.

Lecidea auriculata T. Fries. — Unalaska Island. Apparently the first report for Alaska.

Mycoblastus sanguinarius (L.) Norm. var. alpinus (E. Fries) Stein. — Rather common; Unalaska Island, Atka Island, Kodiak Island.

Bacidia alaskensis (Nyl.) Zahlbr. (Pl. VIII, Fig. 2). — Unalaska Island; identified by Magnusson. The species was described by Nylander from material collected in Alaska by Dr. Bean in 1880. Apparently this is the first report of its collection since the original material for which no definite locality is given.

Rhizocarpon alpicolum (Wahl.) Rabenh. — Atka Island, Unalaska Island.

Rhizocarpon geographicum (L.) DC. — Unalaska Island.

Rhizocarpon grande (Floerke) Arn. — Unalaska Island.

Cladonia amaurocraea (Floerke) Schaer. — Common; Unalaska Island, Atka Island.

Cladonia bellidiflora (Ach.) Schaer. f. subuliformis (Wahl.) Vainio. Alaska Pen., Atka Island. Apparently the first report for Alaska.

Cladonia chlorophaea (Floerke) Spreng. f. costata (Floerke) Sandst. — Kodiak Island.

Cladonia coccifera (L.) Willd. — Rather common; Unalaska Island, Atka Island.

Cladonia coccifera (L.) Willd. var. pleurota (Floerke) Schaer. — Atka Island.

Cladonia deformis (L.) Hoffm. — Seldovia.

Cladonia fimbriata (L.) E. Fries var. coniocraea (Floerke) Vainio. — Kodiak Island. Apparently the first report for Alaska.

Cladonia gracilis (L.) Willd. var. chordalis (Floerke) Schaer. — Unalaska Island, Unimak Island.

Cladonia gracilis (L.) Willd. var. elongata (Jacq.) Floerke. — Atka Island. Apparently the first report for Alaska.

Cladonia lepidota Nyl. f. cerasphora Lynge. — Seemingly common, Unalaska Island. Apparently the first report for North America.

Cladonia pyxidata (L.) E. Fries. — Atka Island.

Cladonia scabriuscula Sandst. f. conspersa Vainio. — Unalaska Island. Apparently the first report for North America.

Cladonia squamosa (Scop.) Hoffm. — Kodiak Island.

Cladonia uncialis (L.) Web. — Unalaska Island.

Stereocaulon denudatum Floerke. — Common; Unalaska Island, Atka Island, Amlia Island, Unimak Island.

Stereocaulon paschale (L.) Hoffm. — Alaska Pen., Unalaska Island.

Gyrophora anthracina (Wulf.) Ach. — Rather common; Unalaska Island.

Gyrophora arctica Ach. — Common; Atka Island, Unalaska Island, Amlia Island.

Pertusaria communis DC. — Rather common; Unalaska Island, Atka Island.

Pertusaria glomerata (Ach.) Schaer. (Pl. IX, Fig. 1). — Amlia Island.

Lecanora aleutica H. Magn., sp. nov. (Pl. IX, Fig. 2).

Thallus expansus, orbicularis, albescens, centroversus verrucosus vel verrucoso-areolatus, subcrassus, ambitu tenuis in

hypothallum cretaceum fimbriatum distincte radians transiens, CaCl−, KOH−, J−. Apothecia centroversus solum evoluta, sedentia et umbilicata vel breviter podicellata, magna, rotundata, disco testaceo-fusco plano vel leviter convexo margine tenui mox exclusa circumdato. Cortex apothecii subtus late evolutus, cinereo-nubilatus, KOH−. Hypothecium incoloratum. Hymenium mediocre, superiore parte fulvescente non inspersa. Sporae maiores.

Thalli 6–12 cm. or more in diameter, orbicular to somewhat irregular, sordid white, the radiating circumference lighter in color, the central irregular areolae 0.5–1 mm. broad, verrucose, dividing into smaller ones, up to 1 mm. thick, internally dark gray on account of air and granules which dissolve in acids only to a small extent; the cortex 35 μ thick, colorless, with an indistinct similarly colorless surface, hyphae intricate, indistinct, thick-walled with oblong or rounded small cells; the gonidia 8–13 μ across, in more or less globular lumps partly separated by perpendicular strands of hyphae, in a stratum up to 100 μ thick which is very uneven above; the medulla thick, gray, consisting of rather dense, intricate, indistinct, thick-walled hyphae.

Apothecia not numerous, the younger surrounded by a slightly prominent pale margin, the older 3–5 mm. across with excluded margin, the disk more or less dark yellow-brown, plane or slightly convex, 0.7 mm. thick near the margin, provided at the center with a foot 0.8 mm. long and 0.7 mm. thick, in section mostly pale, KOH−; the marginal cortex 40–50 μ thick, the upper part along the hymenium colorless without gonidia, the lower part more or less dark gray with a gonidial stratum, the hyphae perpendicular to the surface, thick-walled in HNO_3, 7–9 μ thick with granular surface, the gray color remaining also in HCL and HNO_3, the small obscuring granules more or less visible in alcohol; the gonidial stratum 100–150 μ thick inside the cortex below the hymenium; the exciple 100–160 μ thick, chondroid, refracting, the lower surface toward the medulla very uneven; the hypothecium about 50 μ thick, gray, I+ more or less pale blue, often only in spots; the hymenium 85 μ high, colorless, I+ blue to sordid blue, the upper 8–10 μ pale brown-orange, in KOH with a yellow mist soon disappearing;

the paraphyses dense, not branched, 1–1.6 μ thick, in KOH discrete, apices hardly swollen, olive-yellow; the asci about 65 × 14 μ, clavate; the spores 8, only a few mature, 13–16 × 7–8 μ, broadly ellipsoid.

Pycnidia not found.

Habitat. — On volcanic stone with *Buellia coniops* and traces of Physcia near *caesia* and *Verrucaria sp.*, probably collected on the shore.

Locality. — Atka Island, Aleutian Islands, Alaska, July 5, 1932, W. J. Eyerdam.

At present it is impossible to determine the relationship of this new species because we have no survey of this large genus and its groups. It resembles in several respects the *Lecanora subfusca* group, but there is no reaction to KOH. At first glance it reminds one of a species of Haematomma on account of its very large characteristic apothecia.

Lecanora gelida (L.) Ach. (Pl. X, Fig. 1). — Quite common, and very characteristic with its large rosette-like apothecia; Unalaska Island, Amlia Island, Unimak Island.

Lecanora straminea (Wahl.) Ach. — Atka Island, Unalaska Island.

Ochrolechia tartarea (L.) Mass. — Quite common; Atka Island, Amlia Island, Unalaska Island.

Haematomma ventosum (L.) Mass. — Unalaska Island.

Parmelia perlata Ach. var. ciliata (Lam. & DC.) Duby. — Seldovia. Apparently the first report for Alaska.

Parmelia physodes (L.) Ach. var. enteromorpha (Ach.) Tuck. — Kodiak Island, Seldovia.

Parmelia saxatilis (L.) Ach. — Quite common and sometimes mixed with the next species; Kodiak Island, Atka Island, Sitkalidak Island.

Parmelia saxatilis (L.) Ach. var. omphalodes (L.) E. Fries. — Rather common; Unalaska Island, Atka Island.

Cetraria fahlunensis (L.) Schaer. — Quite common; Unalaska Island, Atka Island.

Cetraria glauca (L.) Ach. — Kodiak Island.

Cetraria islandica (L.) Ach. — Unalaska Island, Atka Island.

Cetraria lacunosa Ach. (Pl. X, Fig. 2). — Common; Unalaska Island, Atka Island.

Alectoria divergens (Ach.) Nyl. — Unalaska Island.

Alectoria ochroleuca (Hoffm.) Mass. — Unalaska Island, Amlia Island.

Ramalina calicaris (L.) Röhling. — Atka Island, Amlia Island. Apparently the first report for Alaska.

Ramalina farinacea (L.) Ach. — Kodiak Island.

Thamnolia vermicularis (Sw.) Schaer. — Unalaska Island.

Caloplaca elegans (Link.) T. Fries. — Common on rocks along the shore, Unalaska Island, Kodiak Island.

Caloplaca murorum (Hoffm.) T. Fries. — No locality given.

Caloplaca pollinii (Mass.) Jatta. — Unalaska Island.

Buellia coniops (Wahl.) T. Fries. — Atka Island. Apparently the first report for North America.

Physcia stellaris (L.) Nyl. — Unalaska Island.

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PLATE VIII

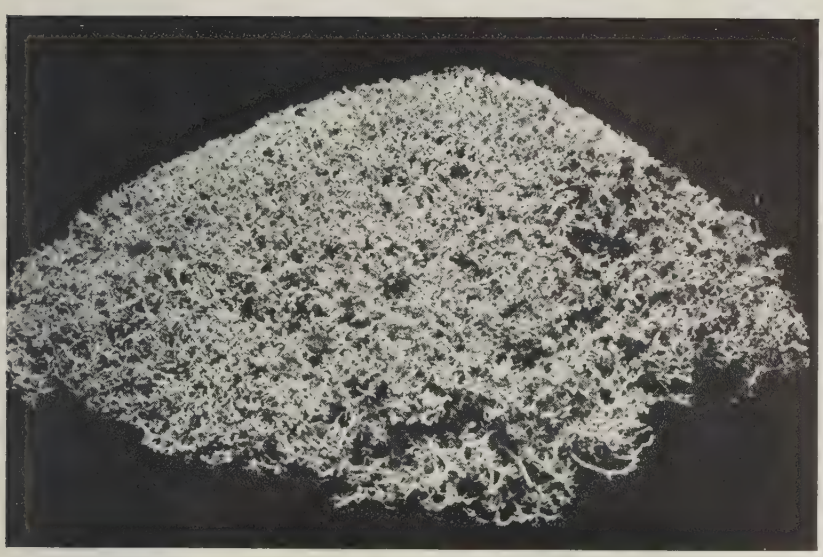

FIG. 1. *Sphaerophorus coralloides* Pers., × ½

FIG. 2. *Bacidia alaskensis* (Nyl.) Zahlbr., × 2

PLATE IX

FIG. 1. *Pertusaria glomerata* (Ach.) Schaer., × 2

FIG. 2. *Lecanora aleutica* H. Magn., × 2

PLATE X

FIG. 1. *Lecanora gelida* (L.) Ach., × 2

FIG. 2. *Cetraria lacunosa* Ach., × 2

ADDITIONS TO THE FLORA OF WASHTENAW COUNTY, MICHIGAN *

FREDERICK J. HERMANN

THE following notes are based on material collected by the writer, chiefly in 1934, but the earlier numbers represent collections of 1926 and 1927.

That the flora of Washtenaw County is still very imperfectly known seems manifest when it is considered that eighty-six vascular plants not reported for the county by Walpole [1] were collected sporadically by the writer, with no intensive or concentrated effort to add to the number of species known from the area. There are probably several reasons why these species have not been previously reported. Some are no doubt very local, such as *Carex pedunculata* and *Cardamine pennsylvanica*, and a few are probably recent introductions, such as *Bromus intermedius* and *Sisymbrium Thalianum*. Again, some are representatives of critical genera whose distinctness from near relatives may not be readily apparent, for example, *Carex Bebbii* and *C. suberecta*, or which may be segregates not yet incorporated into the manuals, for example, *Carex laevivaginata* and *Galinsoga ciliata;* but it is difficult to understand why such plentiful species as *Mariscus mariscoides*, *Carex communis*, *Pyrus coronaria*, *Prunus virginiana*, and *Viburnum Lentago* were not recorded.

Lack of opportunity has prevented a systematic search through the Herbarium of the University of Michigan for further Washtenaw County records, but such a search would unquestionably add many more.

In the following list species preceded by an asterisk have apparently not heretofore been reported for Michigan. As a rule, only one or two localities are cited for species which are common,

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 519.

[1] Walpole, Branson A., *Flora of Washtenaw County, Michigan*, Department of Natural Science, Michigan State Normal College, Ypsilanti, 1924.

although they may be represented in herbaria by other collections. The numbers given after localities are the writer's collection numbers except where otherwise noted. The abbreviations used to indicate herbaria in which specimens of the collections cited have been deposited are here listed:

F — Field Museum Herbarium
G — Gray Herbarium
H — Herbarium of F. J. Hermann
M — University of Michigan Herbarium
Mn — University of Minnesota Herbarium
Mo — Herbarium of the Missouri Botanical Garden
N — National Herbarium
P — Herbarium of the Academy of Natural Sciences of Philadelphia
W — University of Wisconsin Herbarium

Equisetum hyemale L. var. affine (Engelm.) A. A. Eaton. — Locally abundant on partly wooded banks of the Huron River and other streams. Cascade Glen; Nichols Arboretum, *48* (M).

Lycopodium lucidulum Michx. — Plentiful in Mud Lake Bog, *2369* (M).

Picea mariana (Mill) BSP. — The dominant tree in the bog east of Mud Lake, *6455½* (H).

Potamogeton Robbinsii Oakes. — South end of Whitmore Lake, *1661* (H).

Panicum flexile (Gattinger) Scribn. — East shore of Silver Lake, *6427* (M, H).

Phalaris canariensis L. — Apparently rare, but persisting for several years. Pontiac Road, Ann Arbor, *1359* (M).

Muhlenbergia foliosa (R. & S.) Trin. — Frequent. Cady's Corner, *1632* (M).

Alopecurus aequalis Sobol. (*A. geniculatus* L. var. *aristulatus* Torr.). — Common. Pawpaw Woods, *1711* (M); Third Sister Lake, *6194* (M, G, N, P, H).

*Alopecurus agrestris L. — Rare. Waste ground, Packard Road, Ann Arbor, *6184* (H).

Sporobolus neglectus Nash. — Plentiful in sandy field on north bank of Huron River, three and one-half miles southeast of Ypsilanti, *6459* (M, H).

Glyceria borealis (Nash) Batchelder. — Marshy southwest shore of Third Sister Lake, *6192* (M, G, H).

Bromus commutatus Schrad. — Becoming frequent in waste ground. Ann Arbor, *1182* (M, H).

Bromus Kalmii Gray. — Frequent in open oak woods. Cedar Bend, Ann Arbor, *1418* (M).

*Bromus intermedius Guss. — Rare. Waste ground, Packard Road, Ann Arbor, *6225* (N). Determined by Professor Hitchcock, who states that this is the first record for the United States.

Lolium multiflorum Lam. — Occasional in lawns. Ann Arbor, *1642* (M).

Cyperus rivularis Kunth. — Abundant on margin of pond east of Silver Lake, *6435* (M, G, N, P, Mo, F, W, H).

Cyperus erythrorhizos Muhl. — Bank of Huron River one-half mile west of Scio, *6450½* (H).

Cyperus filiculmis Vahl. var. macilentus Fernald. — Apparently more plentiful than the typical form. Michigan Central Railroad siding north of Ann Arbor, *1452* (M, H).

Eleocharis olivacea Torr. — Abundant on quagmires at Mud Lake, and on margin of pond east of Silver Lake, *6430½* (H).

*Eleocharis caribaea (Rottb.) Blake var. dispar (E. J. Hill) Blake. — Abundant on margin of pond east of Silver Lake, *6430* (G, H), *6475* (M). Previous to 1934 known only from the type station, Lake County, Indiana.

Eleocharis Smallii Britton. — Clay margin of pond, Shanghai Pit, *6258* (M, Mo, H).

Eriophorum spissum Fernald (*E. callitrix* of recent manuals, not Cham.). — Plentiful in Mud Lake Bog, *6203* (M, G, P, H). Here near the southern limit of its range.

Mariscus mariscoides (Muhl.) Kuntze (*Cladium mariscoides* (Muhl.) Torr.). — Common in marshes and on sandy shores. Silver Lake, *1620* (M), *6237* (G, H); Cavanaugh Lake, *6237* (M, H).

Carex Sartwellii Dewey. — Occasional. Bog south of Cavanaugh Lake, *6239* (M, H).

Carex convoluta Mack. — Common. White's Woods, Ann Arbor; Cascade Glen, *6228* (H).

*Carex laevivaginata (Kukenth.) Mack. — Frequent. Cascade Glen, *6231* (H).

Carex sterilis Willd. — Fairly common. Marsh south of Cavanaugh Lake, *6218* (M), *6219* (H).

Carex Bebbii Olney. — Frequent. Marsh on Geddes Ave., *1489* (M), and on North Boulevard, Ann Arbor, *1495* (M).

Carex suberecta (Olney) Britton. — Frequent on sandy shores and in marshes. Cavanaugh Lake, *6220* (H), *6250* (G, N).

Carex alata Torr. — Marsh south of Cavanaugh Lake, *6242* (H).

Carex Jamesii Schwein. — Locally plentiful. Cascade Glen, *6227* (M, G, N, P, F, Mo, Mn, H).

Carex communis Bailey. — Common on open oak slopes. White's Woods; Cascade Glen, *5998* (N, P, Mn, Mo, W).

Carex pedunculata Muhl. — Beech-maple woods near Cherry Hill Road, ten miles northeast of Ann Arbor, *C. O. Grassl, 3886* (M, H).

Carex Meadii Dewey (*C. tetanica* Schkuhr var. *Meadii* (Dewey) Bailey). — Plentiful in swamp south of Cavanaugh Lake, *6216* (H).

Carex Woodii Dewey (*C. tetanica* Schkuhr var. *Woodii* (Dewey) Bailey). — Rare. Sparsely wooded bog, south shore of Base Line Lake, *6012* (H).

Carex heterosperma Wahl. — Common on moist, wooded slopes. Cascade Glen, *5999* (M).

Carex gracilescens Steud. — Beech-maple woods near Cherry Hill Road, ten miles northeast of Ann Arbor, *C. O. Grassl, 3887* (M).

Carex glaucodea Tuckerm. — Sterile soil, sparsely wooded steep bank of Huron River, King's Flats, three and one-half miles southwest of Ypsilanti, *6458* (H).

Carex Sprengelii Dewey (*C. longirostris* Torr.). — Local. Moist, open ravine, Cascade Glen, *6226* (M, G, Mo, Mn, F, P, W, H).

Carex Buxbaumii Wahl. (*C. polygama* Schkuhr). — Probably frequent in sandy marshes. South shore of Base Line Lake, *6013* (M, H).

Carex substricta (Kükenth.) Mack. — Marsh south of Cavanaugh Lake, *6213* (H).

Carex viridula Michx. (*C. Oederi* Retz. var. *pumila* (Cosson & Germain) Fernald). — Locally plentiful. South shore of Cavanaugh Lake, *6247* (M, G, N).

Carex rostrata Stokes. — Marshy shore of Second Sister Lake, *6194½* (H).

Juncus macer S. F. Gray var. Williamsii (Fernald) Fernald (*J. tenuis* of recent manuals, not Willd., var. *Williamsii* Fern.). — Frequent in sterile soil. Shanghai Pit, *6256* (G, Mo, H).

Juncus effusus L. var. solutus Fernald & Wiegand. — Common in marshes. Geddes, *6270* (M, G, P, H). True *J. effusus* does not occur, so far as known, in America.

Juncus brachycephalus (Engelm.) Buch. — Common on sandy shores and in marshes. Silver Lake, *6429* (M, G, N, P, F, H); Huron River Drive, two miles east of Ann Arbor, *6452* (M, W, H).

Juncus acuminatus Michx. — Apparently local. Wet sandy shore of Third Sister Lake, *6444* (M, G, H).

Juncus alpinus Vill. var. fuscescens Fernald. — Wet, sandy shore of pond, Silver Lake, *6434* (M, H).

Juncus alpinus Vill. var. rariflorus Hartm. (*J. alpinus* var. *insignis* Fries). — Frequent on wet, sandy shores. Cavanaugh Lake, *6249* (M, G, N, P, F, H). True *J. alpinus* Vill. has not been found in Michigan.

Juncus articulatus L. var. obtusatus Engelm. — Sandy west shore of Whitmore Lake, *6455* (M, H). The southernmost record for Michigan.

Luzula campestris (L.) DC. var. multiflora (Erhr.) Celak. — Common on oak slopes. Nichols Arboretum, Ann Arbor, *6009* (H). Typical *L. campestris* is Eurasian.

Corallorrhiza maculata Raf. — Woods west of Chelsea, *6422½* (H).

Salix rostrata Richards. — Swamp bordering West Lake, *1666* (M).

Betula pumila L. — Swamp bordering Cavanaugh Lake, *6238* (P, H).

Polygonum Persicaria L. — Common in waste ground. Pontiac Road, Ann Arbor, *1252* (M).

Alyssum alyssoides L. — Frequent in clearings. Steinbach Woods, *1054* (M); Delhi; Barton Dam, Ann Arbor, *1142* (M).

Sisymbrium Thalianum (L.) J. Gay. — Waste ground, southern bank of Huron River, Cedar Bend, *63* (M). First noted here in 1926; now rapidly spreading and becoming frequent.

Draba reptans (Lam.) Fern. var. micrantha (Nutt.) Fern. (*D. caroliniana* Walt.). — Sandy field near Base Line Lake, *6010½* (H).

Armoracia rusticana Gaertn. (*Radicula Armoracia* (L.) Robinson). — Occasionally escaping and persisting along roadsides. Nichols Arboretum, *1154* (M).

Cardamine pennsylvanica Muhl. — Rare. Stream bank in woods, Hickory Flats, *2380* (M).

Sedum ternatum Michx. — Abundant on wooded slope of Huron River west of Pontiac Road, Ann Arbor, *1137* (M).

Ribes americanum Mill. (*R. floridum* L'Hér). — Apparently spontaneous in thickets, Nichols Arboretum, *125* (M), *2392* (M).

Ribes nigrum L. — Occasional. Cady's Corner, *1059* (M).

Pyrus coronaria L. — Frequent in open woods. Cascade Glen; Nichols Arboretum; Cedar Bend, *139* (M).

Pyrus melanocarpa (Michx.) Willd. — Frequent in moist woods and swamps. Cady's Corner, *1061* (M).

Geum laciniatum Murr. (*G. virginianum* of recent authors, not L.). — Wooded bank of Huron River west of Pontiac Road, Ann Arbor, *1233* (M).

Rubus occidentalis L. — Frequent. Woods west of Packard Road, Ann Arbor, *1200* (M).

Rubus flagellaris Willd. (*R. villosus* Ait.). — Shore of West Lake, *1152* (M).

Rosa setigera Michx. — Thicket near University Hospital, Ann Arbor, *1332* (M).

Rosa palustris Marsh. — Marsh, Third Sister Lake, *1377* (M).

Prunus virginiana L. — Common in thickets and on stream banks. Nichols Arboretum; Cascade Glen, *126* (M).

Euonymus atropurpureus Jacq. — Roadside thickets. Hickory Flats, *2388* (M).

Viola rostrata Pursh. — Third Woods, southwest of Ann Arbor, *113* (M).

Vaccinium corymbosum L. — Swamp, Cady's Corner, *86* (M).

*Anchusa officinalis L. — Waste ground, Ann Arbor, *1480* (M).

Plantago cordata Lam. — Hickory Flats, *2387* (M).

Galium labradoricum Wiegand. — Swamp, Cavanaugh Lake, *1716* (M).

Galium Claytoni Michx. — Marsh, Third Sister Lake, *1379* (M).

Viburnum Lentago L. — Fairly common. Edge of woods, Cascade Glen, *167* (M); Nichols Arboretum, *163* (M), *938* (M).

Valeriana officinalis L. — Roadside, Geddes Ave., Ann Arbor, *1195* (M).

Campanula uliginosa Rydb. — Marshy shore of Third Sister Lake, *1372* (M).

Sonchus oleraceus L. — Occasional. Field northwest of Nichols Arboretum, *1415* (M).

Xanthium italicum Mor. (*X. commune* Britton). — Frequent. Cascade Glen, *1609* (M).

Vernonia altissima Nutt. — Edge of low woods, Nichols Arboretum, *6426* (M, N, H).

Artemisia Absinthium L. — Michigan Central Railroad siding north of Ann Arbor, *1337* (M).

Galinsoga ciliata (Raf.) Blake (*G. parviflora* Cav. var. *hispida* DC.). — Common on lawn extensions and waste ground. Geddes Ave., Ann Arbor, *993* (M), *1293* (M).

University of Michigan

NEW OEDOGONIA COLLECTED IN CHINA. III *

CHIN-CHIH JAO

IN THE last two volumes of this publication (19 : 83–92; 20 : 57–63) the writer described twelve new species and varieties of Oedogonium from China. This paper contains descriptions of seven new kinds, which were collected at Pa Heien and Chiangpei, stations in East Szechwan, West China, by Miss Chun Jao, Mrs. C. S. Lung, and Mr. P. C. Chen. The chief cities of these districts are Chungking and Chiangpei, near which the present group of new species was gathered. They were collected on rice farms; one was also found in a well.

The writer's descriptions of new species and varieties during the last two years are the first reports upon the algal flora of this region. In several years of collecting he has recognized about seventy members of this genus from Szechwan, including new and known species, varieties, and forms. It is proposed to publish later on a monograph of these plants.

Oedogonium parvum, sp. nov.

(Tab. XI, Figg. 1–2)

Oedogonium monoicum; oogoniis singulis, depresso-globosis, poro superiore apertis, rimiformibus; oosporis forma oogoniis similibus et ea plane complentibus vel fere complentibus; membrana sporae laevi; antheridiis 1- vel 4-seriatis, hypogynis, subepigynis vel sparsis; spermatozoidiis singulis; cellula terminali obtusa; cellula basali leviter tumida.

Cellulae vegetativae	3.2–6.4 μ diam., 9.6–29.0 μ long
Oogonia	17.0–19.0 μ diam., 13.0–16.0 μ long
Oosporae	16.0–17.0 μ diam., 11.0–13.0 μ long
Cellulae antheridii	3.2–6.4 μ diam., 3.2–6.4 μ long

Monoecious; oögonium solitary, depressed-globose, pore superior, rimiform; oöspore of the same form as the oögonium and filling or

* Papers from the Department of Botany of the University of Michigan, No. 539.

nearly filling it; spore wall smooth; antheridia 1–4, hypogynous, subepigynous or scattered; sperm 1; terminal cell obtuse; basal cell slightly tumid.

Vegetative cells	3.2–6.4 μ diam., 9.6–29.0 μ long
Oögonia	17.0–19.0 μ diam., 13.0–16.0 μ long
Oöspores	16.0–17.0 μ diam., 11.0–13.0 μ long
Antheridia	3.2–6.4 μ diam., 3.2–6.4 μ long

This species is characterized by small size and superior pore, which distinguish it from the related species *Oedogonium cryptoporum* Wittrock and *Oe. cryptoporum* Wittrock var. *vulgare* Wittrock.

Collected on a rice farm near Tzü-Ch'i-Kuo, a market town, about seventeen miles west of Chungking, Szechwan, West China, December, 1933. The filaments are scattered in *Oedogonium dentireticulatum* Jao, *Oe. suecium* Wittrock, and *Mougeotia parvula* Hassall. Type in C. C. Jao collections and Herb. Univ. Mich., No. S144.

Oedogonium chungkingense, nom. nov.
(= *Oe. cymatosporum* Wittrock & Nordstedt var. *chungkingense* Jao, 1934)

The dimensions of *Oedogonium chungkingense* Jao are much smaller than those of *Oe. cymatosporum* Wittrock & Nordstedt. The difference is so great that it seems better to give these Chinese plants specific rank. A related species, *Oe. subcymatosporum* Jao, was found in the writer's collections from Chungking; it is quite similar to this species, but *Oe. subcymatosporum* has much larger dimensions of its vegetative cells, which are only 1–2 diameters in length, and also the median spore wall is densely punctate.

Oedogonium subcymatosporum, sp. nov.

(Tab. XI, Figg. 3–5)

Oedogonium monoicum; oogoniis 1–3, subglobosis vel depresso-globosis, poro mediano apertis, rimiformibus; oosporis depresso-globosis, maturitate fuscescente, oogonia complentibus vel fere complentibus; membrana triplici, mesosporio dense punctato; antheridiis 1- vel 3-cellularibus, hypogynis, subepigynis vel sparsis; spermatozoidiis singulis; cellulis vegetativis plerumque diametro semel vel bis longioribus; cellula terminali obtusa.

Cellulae vegetativae	8–15 μ diam., 10–29 μ long
Oogonia	22–26 μ diam., 14–22 μ long
Oosporae	19–24 μ diam., 13–18 μ long
Cellulae antheridii	7–10 μ diam., 6–8 μ long

Monoecious; oögonia 1–3, subglobose or depressed-globose, pore median, rimiform; oöspore depressed-globose, yellowish brown at maturity, filling or nearly filling the oögonium; spore wall of three layers, median layer densely punctate; antheridia 1–3, hypogynous, subepigynous or scattered; sperm 1; vegetative cells usually 1–2 diameters long; terminal cell obtuse.

Vegetative cells	8–15 μ diam., 10–29 μ long
Oögonia	22–26 μ diam., 14–22 μ long
Oöspores	19–24 μ diam., 13–18 μ long
Antheridia	7–10 μ diam., 6–8 μ long

This species is nearest *Oedogonium cymatosporum* Wittrock & Nordstedt and *Oe. chungkingense* Jao. It differs, however, from the first in having smaller dimensions of all cells; from the second, in its greater size, especially the vegetative cells and antheridia; and from both in usually having the vegetative cells only 1–2 diameters long and the median spore wall densely punctate.

Collected on a rice farm near Chungking, August, 1930. The filaments are scattered in vegetative plants of Zygnemataceae. Type in C. C. Jao collections and Herb. Univ. Mich., No. S323.

Oedogonium calosporum, sp. nov.

(Tab. XI, Figg. 11–12)

Oedogonium dioicum, macrandrium; oogoniis 1–2, obovoideo-globosis vel obovoideis, poro superiore apertis; oosporis globosis vel subglobosis, oogoniis non conformantibus; cellulis suffultoriis cylindricis; membrana sporae triplici; episporio scrobiculato; antheridiis 1- vel 2-seriatis; spermatozoidiis binis, divisione horizontali natis; cellula terminali obtusa; cellula basali subtiliter tumida.

Cell. veg., planta masc.	10–13 μ diam., 48–108 μ long
Cell. veg., planta fem.	11–16 μ diam., 48–76 μ long
Oogonia	35–41 μ diam., 41–48 μ long
Oosporae	30–32 μ diam., 32–35 μ long
Cell. antheridii	13 μ diam., 13 μ long

Dioecious, macrandrous; oögonia 1–2, obovoid-globose to obovoid, pore superior; oöspore globose to subglobose, not filling the

oögonium; spore wall of three layers, outer spore wall scrobiculate; antheridia 1–2; sperms 2, division horizontal; terminal cell obtuse; basal cell slightly tumid.

Vegetative cells, male plant..	10–13 μ diam., 48–108 μ long
Vegetative cells, female plant	11–16 μ diam., 48–76 μ long
Oögonia	35–41 μ diam., 41–48 μ long
Oöspores	30–32 μ diam., 32–35 μ long
Antheridia	13 μ diam., 13 μ long

This species is nearest *Oedogonium punctatum* Wittrock, but differs from it in having smaller dimensions of all cells, and oöspores not filling the oögonium and in being mostly globose.

Collected on a rice farm, Hsiao-Lung-Kan, a small market town, about fifteen miles west of Chungking, November 4, 1934. Mixed with *Oedogonium crispum* (Hassall) Wittrock var. *gracilescens* Wittrock and *Oe. intermedium* Wittrock, the filaments are attached to rotten leaves of water grasses. Type in C. C. Jao collections and Herb. Univ. Mich., No. S633.

Oedogonium subrupestre, sp. nov.

(Tab. XI, Figg. 6–10)

Oedogonium monoicum; oogoniis singulis, raro binis, obovoideo-globosis vel obovoideis, operculo apertis, circumscissione superiore; oosporis oogoniis conformantibus et fere complentibus; membrana laevi; antheridiis 1- vel 4-cellularibus, subepigynis vel sparsis; spermatozoidiis binis, divisione horizontali natis; cellula terminali acuminata vel setiformi, seta hyalina, frequenter 288 μ longa; cellula basali leviter tumida.

Cellulae vegetativae	17–24 μ diam., 25–85 μ long
Oogonia	41–45 μ diam., 48–52 μ long
Oosporae	38–44 μ diam., 46–50 μ long
Cellulae antheridii	16–19 μ diam., 5–10 μ long

Monoecious; oögonium 1, rarely 2, obovoid-globose to obovoid, operculate, division superior; oöspore the same as the oögonium and nearly filling it, spore wall smooth; antheridia 1–4, subepigynous or scattered; sperms 2, division horizontal; terminal cell acuminate or extended into a long hyaline seta up to 288 μ long; basal cell slightly tumid.

Vegetative cells	17–24 μ diam., 25–85 μ long
Oögonia	41–45 μ diam., 48–52 μ long
Oöspores	38–44 μ diam., 46–50 μ long
Antheridia	16–19 μ diam., 5–10 μ long

This new species is nearest *Oedogonium rupestre* Hirn and its form *pseudoautumnale* Hirn. It differs from them, however, in having lesser dimensions of all cells, the oöspores not globose in form, and the terminal cells acuminate or setiform.

Collected on a rice farm near Tzü-Ch'i-Kou, a market town, about seventeen miles west of Chungking, December, 1933. The filaments are scattered in *Spirogyra Hassallii* (Jenn.) Petit, *S. cylindrica* Czurda, *Zygnema carinthiacum* Beck, *Vaucheria sessilis* (Vauch.) De Candolle, and *Oedogonium macrandrium* Wittrock var. *propinquum* (Wittrock) Hirn. Type in C. C. Jao collections and Herb. Univ. Mich., No. S103.

Oedogonium dentireticulatum, sp. nov.

(Tab. XII, Figg. 1–3)

Oedogonium dioicum, nannandrium, gynandrosporum; oogoniis solitariis, subglobosis vel transverse vel longitudinaliter depresso-globosis, poro mediano vel inframediano apertis; oosporis forma oogoniis similibus et ea complentibus; episporio irregulariter et interrupte reticulato et dentato, dentibus a reticulis dilatis et longitudine mutabilibus; cellulis suffultoriis plus minusve tumidis; androsporangiis 1- vel 2-seratis, sparsis; nannandribus in cellulis suffultoriis sitis, stipite paululum curvato, antheridiis exterioribus, 1- vel 2-cellularibus; filamentis saepe basi et apice gracilioribus; cellula terminali obtusa; cellula basali abbreviata et tumida.

Cellulae vegetativae	10–16 (–19)	μ diam., 41–96 μ long
Oogonia	42–55	μ diam., 48–58 μ long
Oosporae (cum dentibus)	39–52	μ diam., 45–52 μ long
Cellulae suffultoriae	19–23	μ diam., 55–64 μ long
Androsporangia	15–16	μ diam., 16–20 μ long
Nannandris stipes	8–10	μ diam., 19–26 μ long
Cellulae antheridii	5–6	μ diam., 6–8 μ long
Cellulae basales	13–18	μ diam., 37–58 μ long

Dioecious, nannandrous, gynandrosporous; oögonium solitary, subglobose to transversely or longitudinally depressed-globose, pore

median or inframedian; oöspore of the same form as the oögonium and filling it; outer spore wall irregularly and interruptedly reticulate and echinate, teeth spreading out from the reticulations and varying in length; suffultory cell more or less swollen; androsporangia 1–2, scattered; dwarf male on the suffultory cell, stipe a little curved; antheridia exterior, 1–2; filament often more slender at tip and base; terminal cell obtuse; basal cell shortened and tumid.

Vegetative cells	10–16 (–19) μ diam., 41–96 μ long
Oögonia	42–55 μ diam., 48–58 μ long
Oöspores (with teeth)	39–52 μ diam., 45–52 μ long
Suffultory cells	19–23 μ diam., 55–64 μ long
Androsporangia	15–16 μ diam., 16–20 μ long
Male stipes	8–10 μ diam., 19–26 μ long
Antheridia	5–6 μ diam., 6–8 μ long
Basal cells	13–18 μ diam., 37–58 μ long

This is the only known species which has the outer spore wall combining the characters of reticulations and teeth.

Collected on rice farms near Tzü-Ch'i-Kou, a market town, about seventeen miles west of Chungking, December, 1933 (S106, S144, and S154). The filaments are scattered in *Oedogonium crispum* (Hassall) Wittrock, *Oe. suecium* Wittrock, *Oe. Landsboroughi* (Hassall) Wittrock, *Oe. parvum* Jao, *Mougeotia parvula* Hassall, *M. scalaris* Hassall, *Spirogyra Spreeiana* Rabenhorst, and *Zygnema carinthiacum* Beck. Type in C. C. Jao collections and Herb. Univ. Mich., No. S154.

Oedogonium spiralidens Jao f. **amplum**, f. nov.

(Tab. XII, Figg. 4–5)

Forma mensuris cellularum omnium maioribus et dentibus oosporae densioribus longioribusque quam in forma typica; aliter ut in specie.

Cellulae vegetativae	16–26 μ diam., 38–87 μ long
Oogonia	53–58 μ diam., 50–58 μ long
Oosporae (cum dentibus)	50–55 μ diam., 45–55 μ long
Cellulae suffultoriae	26–35 μ diam., 57–77 μ long
Nannandris stipes	13 μ diam., 40 μ long
Cellulae antheridii	? ?

This form has the dimensions of all cells greater and the teeth of the oöspore membrane denser and longer than in the typical form; it is otherwise like the species.

Vegetative cells	16–26 μ diam., 38–87 μ long
Oögonia	53–58 μ diam., 50–58 μ long
Oöspores (with teeth)	50–55 μ diam., 45–55 μ long
Suffultory cells	26–35 μ diam., 57–77 μ long
Male stipes	13 μ diam., 40 μ long
Antheridia	? ?

Collected on a rice farm near Tzü-Ch'i-Kuo, a market town, about seventeen miles west of Chungking, December, 1933. Filaments mixed with many other filamentous algae. Type in C. C. Jao collections and Herb. Univ. Mich., No. S106 : 2.

Oedogonium crassidens, sp. nov.

(Tab. XII, Figg. 6–8)

Oedogonium dioicum, nannandrium; oogoniis singulis, depresso-globosis, poro superiore apertis; oosporis forma oogoniis similibus et ea complentibus; membrana oosporarum triplici; episporio subtiliter granulato, costato, costis spiralibus 4–7 marginibus valide denticulatis, anastomosantibus in polis; mesosporio laevi; cellulis suffultoriis tumidis; nannandribus paululum curvatis, in oogoniis; antheridiis exterioribus, 1- vel ?-cellularibus; cellula terminali obtusa.

Cellulae vegetativae	13–22 μ diam., 25–90 μ long
Oogonia	48–64 μ diam., 41–61 μ long
Oosporae (cum dentibus)	45–58 μ diam., 38–48 μ long
Cellulae suffultoriae	29–32 μ diam., 32–58 μ long
Nannandris stipes	12–13 μ diam., 32 μ long
Cellulae antheridii	9–10 μ diam., 8–12 μ long

Dioecious, nannandrous; oögonium solitary, depressed-globose, pore superior; oöspore of the same form as the oögonium and filling it; spore wall of three layers, outer wall granulate and marked by 4–7 spiral ribs uniting and anastomosing at the pole, the edge of the ribs strongly dentate; suffultory cell tumid; dwarf male slightly curved, on the oögonium; antheridia exterior, 1–?; terminal cell obtuse.

Vegetative cells	13–22 μ diam., 25–90 μ long
Oögonia	48–64 μ diam., 41–61 μ long
Oöspores (with teeth)	45–58 μ diam., 38–48 μ long
Suffultory cells	29–32 μ diam., 32–58 μ long
Male stipes	12–13 μ diam., 32 μ long
Antheridia	9–10 μ diam., 8–12 μ long

This species is characterized by the depressed-globose oögonia and oöspores, the granulate and dentately ribbed outer spore wall and the smaller vegetative cells, which distinguish it from the nearest related species, *Oe. stellatum* Wittrock.

Collected in a well near Liu-Chia-T'an, a suburb west of Chiangpei, December 12, 1933 (S555); on rice farms near Hsian-Kuo-Shih, about seven miles west of Chiangpei, December 27, 1933 (S566 and S582); on a rice farm, Li-Tze-Pa, about seven miles west of Chungking, May, 1934 (S623). Filaments scattered among many other filamentous algae. Type in C. C. Jao collections and Herb. Univ. Mich., No. S623.

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EXPLANATION OF PLATE XI

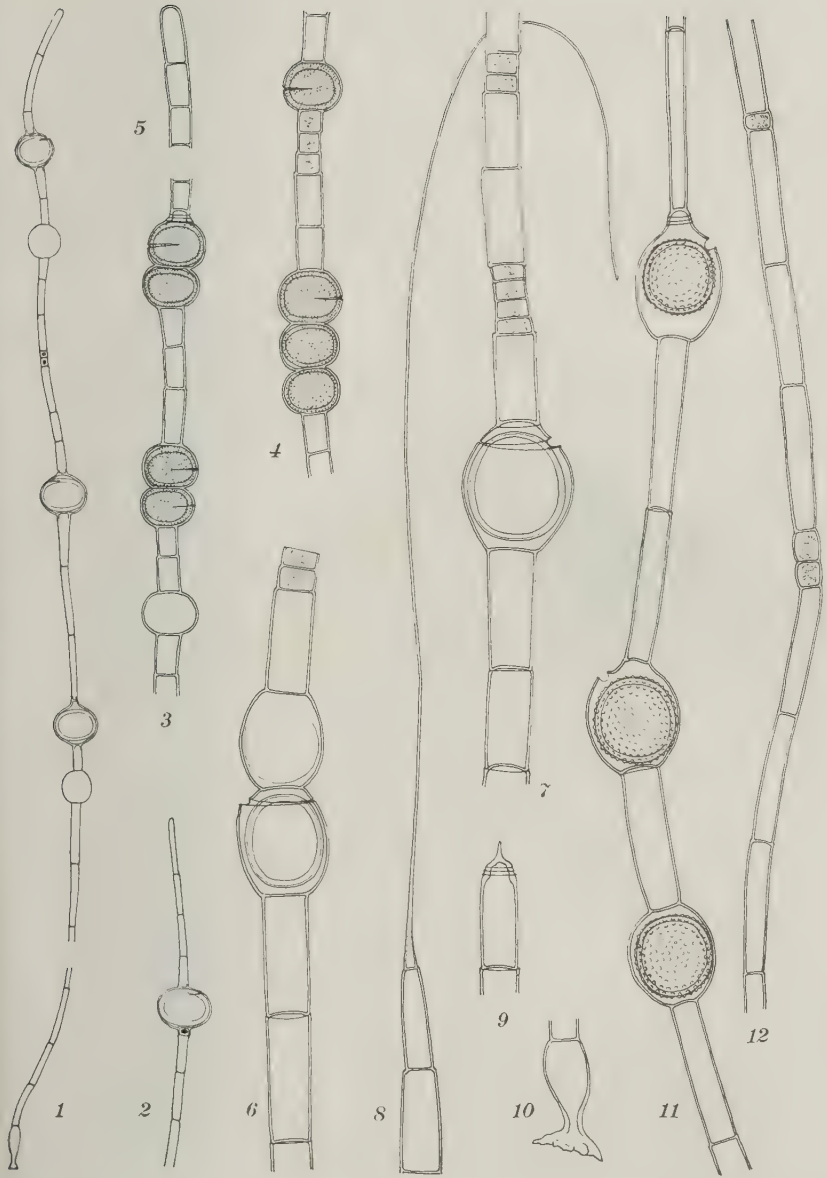
Figs. 1–2. *Oedogonium parvum*, sp. nov. (× 360). Figure 1, a fruiting filament, with five oögonia and two antheridia; Figure 2, an upper part of the filament, showing a mature oögonium, a hypogynous antheridium, and the obtuse terminal cell

Figs. 3–5. *Oedogonium subcymatosporum*, sp. nov. (× 360). Figure 3, part of the filament, showing three series of oögonia; Figure 4, part of the filament, with two series of oögonia and one series of hypogynous antheridia; Figure 5, an upper part of the filament, showing the obtuse terminal cell

Figs. 6–10. *Oedogonium subrupestre*, sp. nov. (× 360). Figure 6, part of the filament, showing two oögonia and two subepigynous antheridia; Figure 7, part of the filament, with two series of antheridia and one mature oögonium; Figure 8, an upper part of the filament, showing the terminal cell extended into a long seta; Figure 9, an acuminate terminal cell; Figure 10, basal cell

Figs. 11–12. *Oedogonium calosporum*, sp. nov. (× 360). Figure 11, part of the filament, with three mature oögonia; Figure 10, part of the male filament, showing two series of antheridia

PLATE XI



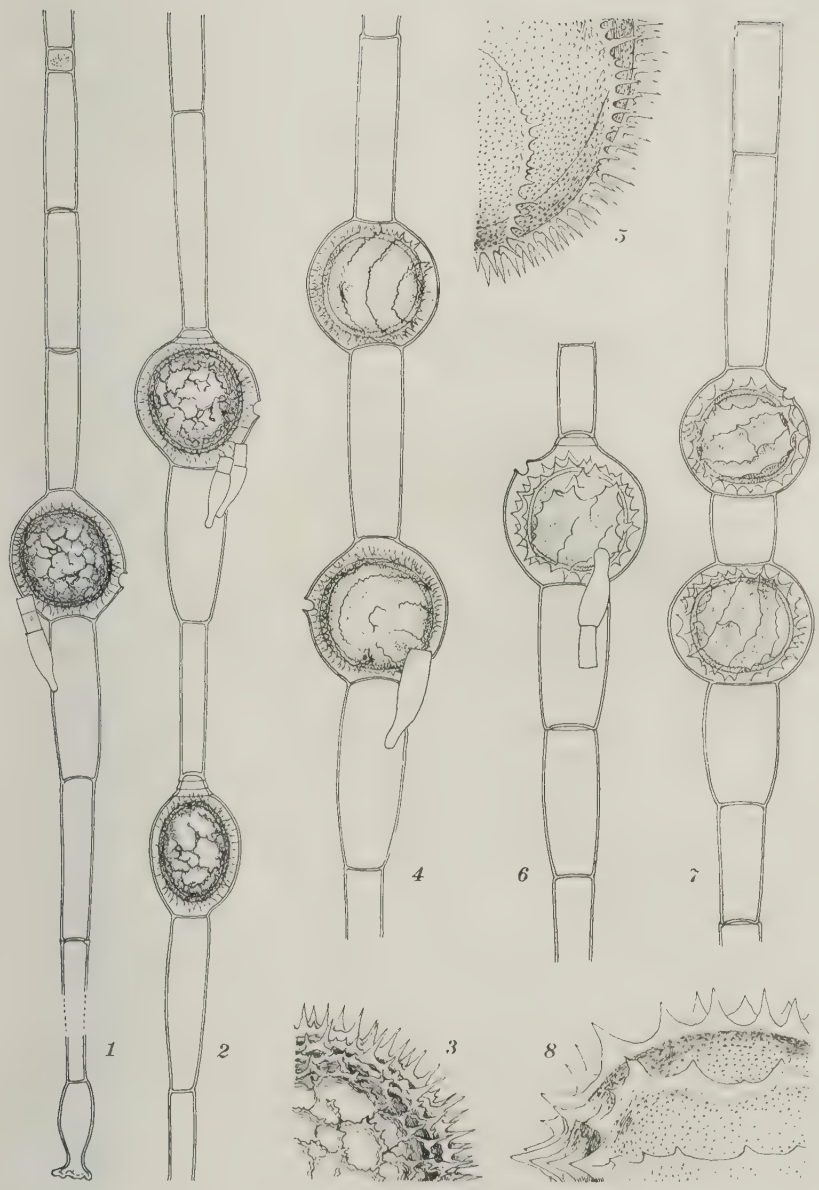
EXPLANATION OF PLATE XII

FIGS. 1–3. *Oedogonium dentireticulatum*, sp. nov. Figure 1 (× 360), lower part of the filament, showing an oögonium with an inframedian pore and containing a mature oöspore, an isolated androsporangium, a dwarf male on the suffultory cell, and a tumid basal cell; Figure 2 (× 360), part of the filament, with two oögonia of different form, the tumid suffultory cells and two dwarf males; Figure 3 (× 1,500), part of the mature oöspore, showing the dentately reticulate outer spore wall

FIGS. 4–5. *Oedogonium spiralidens* Jao forma *amplum*, f. nov. Figure 4 (× 360), part of the filament, showing two mature oögonia and a dwarf male on the suffultory cell; Figure 5 (× 1,500), part of the mature oöspore, showing the dentately ribbed and granulate outer spore wall

FIGS. 6–8. *Oedogonium crassidens*, sp. nov. Figure 6 (× 360), part of the filament, with a dwarf male on the mature oögonium; Figure 7 (× 360), part of the filament, with two depressed-globose oögonia; Figure 8 (× 1,500), part of the mature oöspore, showing the outer spore wall with strongly toothed ribs and fine granules

PLATE XII



NOTES ON NEW OR UNUSUAL MICHIGAN DISCOMYCETES. III *

BESSIE B. KANOUSE

THIS paper lists twenty-five species of Discomycetes, twenty-four of which are new records for the state flora. One new species and one new combination are included: *Apostemidium obconicum*, sp. nov., and *Humarina subsemiimmersa* (v. H.) Kanouse.

All collections cited have been determined by the author and are preserved in the Herbarium of the University of Michigan.

Grateful acknowledgment is given to Dr. E. B. Mains for the photographs.

List of Species

Apostemidium obconicum, sp. nov.[1] (Pl. XIII, Figs. 1–3).— Apothecia gregarious, short-pedicellate, cylindric to cone-shaped, 1.5 2 mm. high, 0.5 0.75 mm. wide, tapering gradually downward to a narrow stalklike basal attachment, glistening white throughout when fresh, drying white rarely with a slight ochraceous tint, soft, waxy, subgelatinous, exciple thick, composed of large, thick-walled, isometric, hyaline cells, hypothecium reduced to a small central core of thin-walled hyaline hyphae, hymenium plane, bordered by a fringe of delicate excipular cells, more or less evanescent; asci long, cylindric, narrow, 8-spored, spores in a parallel fascicle, 180–250 × 9 μ, ascus pore colored faintly blue with iodine; spores long-filiform, hyaline, multiseptate, curved, frequently S-shaped, 140 200 × 1 1.5 μ, forming a silky fluff over dry apothecia; paraphyses simple, unbranched, slender, abruptly clavate above, reaching 4–6 μ at the apex.

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 537.

[1] **Apostemidium obconicum**, sp. nov. — Apotheciis breviter stipitatis, marginatis, cylindricis vel conicis, 1.5–2 mm. altis, 0.5–0.75 mm. latis, nitenter albis; disco plano; ascis cylindricis, tenuibus, 8-sporis, 180–250 × 9 μ; sporidiis filiformibus, hyalinis, arcuatis, 140–200 × 1–1.5 μ; paraphysibus simplicibus, gracilibus, parte superiore abrupte clavatis, apice usque ad 4–6 μ diametro.

On old sticks of *Chamaedaphne calyculata* (L.) Moench., buried from 3 inches to 2 feet in sphagnum and débris at bases of Chamaedaphne bushes, Mud Lake Bog, Whitmore Lake, May 28, 1933. Type collected by A. H. Smith, J. L. Lowe, and J. B. McFarland (S. 33–105).[2]

The genus Apostemidium was erected by Karsten (10). The apothecia are sessile or turbinate, whereas in Vibrissea, a closely related genus, the apothecia are seated upon a very definite stalk. Durand (2) recognized two North American species of Apostemidium: *A. Guernisaci* (Cr.) Boud. and *A. vibrisseoides* (Pk.) Boud. The apothecia in these two species are broadly sessile, and the outside of the apothecia is dark-colored. Through the kindness of Dr. H. D. House, curator in the Herbarium of the New York State Museum, I have had the opportunity to examine the type of *A. vibrisseoides.* Illustrations in Plate XIII show the striking difference between Peck's species and *A. obconicum.*

In reviewing the literature and examining the illustrations of Apostemidium species, I found only one reference to plants with light color and to the presence of a stalk. Lagarde (11) described the fully developed fungus that he called *A. vibrisseoides,* as having a short pedicel, which was sometimes reduced to a black attachment, and a white to ivory or pale ochraceous color. It seems fairly certain, although his brief description prevents one from drawing definite conclusions on the matter, that he was observing a fungus very like *A. obconicum* rather than *A. vibrisseoides.* His account of the morphological development in his fungus agrees with that seen in *A. obconicum.* Phillips (15) likewise described the development of *Vibrissea turbinata* (*A. vibrisseoides*), which is similar, as is also the species of Durand's account (2). Their observations and my own on *A. obconicum* are alike in the following respects: The first appearance is as a small, conical protuberance, which in maturity possesses a small central structure of parallel hyphae surrounded by a thick layer of isometric excipular cells. The hymenium is plane and is bordered by a fragile remnant of the excipular cells. The characters of the asci, spores, and paraphyses are similar.

A comparison of *A. obconicum* with the published species

[2] The letters M. and S. used with the collection numbers refer to the collectors, E. B. Mains and A. H. Smith, respectively.

shows clearly that it cannot be considered any of these. The white color throughout, together with the extreme turbinate shape of the fungus, which takes on the appearance of a definite stalk in dried apothecia, are the chief distinguishing characters. *A. obconicum* forms a transition species between the genera Apostemidium and Vibrissea.

Belonidium juncisedum (Karst.) Rehm. — On decaying *Scirpus sp.*, Trout Lake, Aug. 24, 1933, E. B. Mains (33–478).

Coryne solitaria Rehm. — On a rotting log and on sticks in running water, Big Bay, June 13, 1933, Mains (33–324); Harbor Springs, Aug. 17, 1933, Smith (33–658). The plants in these collections are well described by Rehm (16).

Humarina fusispora (Berk.) Seaver. — On rotting leaves, Marquette, Sept. 9, 1933, Mains and Smith (M. 33–633). This species is easily distinguished by the large fusoid spores.

Humarina subsemiimmersa (v. H.) Kanouse, comb. nov. — On decaying leaves of *Populus sp.*, Pinckney, July 2, 1931, Smith (31–1178); on rotting leaves in a cedar swamp, Cross Village, Aug. 19, 1933, Mains (33–442). This is a small fungus with conspicuous paraphyses. They are long, slender, and flexuous, and bent at the tips. In this they resemble paraphyses found in the genus Otidea. They are filled with a substance that gives them a rust-brown color. Von Höhnel (4) called the fungus *Humaria subsemiimmersa.*

Hyalinia crenato-marginata v. H. — On wet decaying logs, Stockbridge, July 9, 1930, Smith (31–1180); Harbor Springs, June 3, 1933, Smith (33–120); Harbor Springs, Aug. 18, 1933, Mains (33–425). This fungus is exceedingly small, measuring less than 600 μ in diameter. The asci are only 25 μ in length and the spores are correspondingly small, $6–8 \times 0.5–1\ \mu$. They are somewhat thicker at one end and are slightly curved. The paraphyses are very characteristic in appearance in that they are tipped with an amorphous substance which comes off easily in water and leaves the usual saucer-shaped enlargment at the apices. A superficial examination gives the impression of the existence of an epithecium. Von Höhnel (5) has given a good description of his species.

Hyalinia rosella (Quél.) Boud. — On decaying log, Emerson, Aug. 25, 1933, Mains (33–484). This species also has a covering

of granular material at the surface of the hymenial layer. Our specimens agree well with the description and the illustrations given by Boudier (1).

Ionomidotis irregularis (L. v. S.) Durand. — Among moss on rotting logs, Newberry, Aug. 30, 1933, Mains (33-564); Munising, Sept. 7, 1933, Mains (33 620). This interesting species was fully described and discussed by Durand (3). It was there reported for the eastern United States only. These collections from northern Michigan establish a midwestern station, and a collection in the University Herbarium made at Mt. Hood, Oregon, Oct. 10, 1922, by L. E. Wehmeyer, extends the limits of distribution to the Pacific Coast. This genus seems to have escaped the notice of botanists, since reference to it is lacking in some of the well-known sources where one might expect to find it mentioned. The species is distinguished by means of the purple color that appears when a specimen is crushed in water, and by the colored, deciduous, lance-shaped heads of the paraphyses.

Lachnella papillaris (Bull.) Karst. — On submerged sticks in a spring brook, Au Train Falls, Au Train, June 6, 1933, Mains (33 84). Our specimens fit in all respects the description given by Rehm (16), with the exception of the length of the asci. They measure slightly longer in our specimens than they do in those examined by him. The very large crystals at the ends of the hairs are a help in recognizing the species.

Lachnum sulfureum (Pers.) Rehm. — On decaying stems of *Thalictrum dasycarpum* Fisch & Lall., Cross Village, Aug. 21, 1933, E. B. and E. E. Mains (M. 33-468). The apothecia are strigose with very long, rough hairs which give a sulphur color to the cups. The reaction to ammonia is like that given for *L. leucophaeum* (Pers.) Rehm in that the yellow color disappears with its use, whereas the hairs of *L. sulfureum* are said to turn blue. The spore size given by Boudier (1) is $20-28 \times 1.5-2\ \mu$; Rehm gives $8-10 \times 1.5-2\ \mu$. The spores of our plants measure $18-22 \times 1.5-2\ \mu$. Evidently specimens that are passing under the names of these two species of Lachnum need careful study.

Laetinaevia rosella (Rehm) Nannf. — On overwintered stems of *Impatiens sp.* lying in wet piles on bank of Huron River, Dexter, May 19, 1933, Kanouse, Mains, and Smith (M. 33-674). This

fungus was found in abundance and, though small, was conspicuous by the bright salmon color of the apothecia when wet. Nannfeldt (12) has established the genus Lactinaevia and has transferred to it parts of several other genera, among which are species of Orbilia and Calloria. *L. rosella* has appeared under these two genera, but seems more correctly referred to Laetinaevia, as proposed by Nannfeldt.

Lamprospora polytrinchina (Rehm) Seaver. — On wet sand in moss, Newberry, Aug. 30, 1933, Smith and Mains (M. 33-554). This species was collected by Dr. C. H. Kauffman at South Haven, July 10, 1910. So far as known these are the only reports from the state.

Microscypha grisella (Rehm) H. and P. Sydow. — On old wood, Au Train, June 12, 1933, Smith (33-434). This is a minute fungus. The apothecia measure less than .4 mm. in diameter. The genus is distinguished in part by the type of hairs that cover the apothecia. They are tipped with hemispherical knobs. Nannfeldt (12) places the genus in the family Hyaloscyphaceae. The species has been reported only on old fern fronds; however, our plants agree perfectly with the description of those reported on this substratum and also with the specimens examined in Sydow's Mycotheca Germanica Nos. 84, 1004, and 1632, and in Krieger's Fungi Saxonica No. 92. Since our fungus cannot be separated on any basis other than that of substratum, it is not possible to consider it a different species.

Mollisia microcarpa (Fuck.) Sacc. — On wood of *Alnus sp.* lying in water, Big Bay, June 13, 1933, Smith (33-447). Marquette, June 15, 1933, Smith (33-495).

Niptera discolor (Mont. & Fr.) Rehm. — On old wood in running water, Wagner's Falls, Munising, June 9, 1933, A. H. Smith (33-225). This fungus is characterized by the dark exterior of the apothecia, together with the size of the apothecia and the positive reaction of the ascus pore to iodine.

Paxina subclavipes (Rehm) Seaver. — On dung, Dexter, July 22, 1929, Kanouse; on soil, Marquette, E. E. Mains and A. H. Smith (S. 33-506).

Pezizella Teucrii (Fuck.) Rehm. — On wood of *Alnus sp.*, Rock River, Aug. 28, 1927, C. H. Kauffman. This species closely resembles an Orbilia, and might easily be confused with a species in

that genus. Von Höhnel (7) has pointed out that it probably represents a transitional form.

Pezizellaster transiens v. H. — On wet, rotting wood, Pinckney, July 4, 1930, Smith (33–1179). The specimens in this collection are perfectly described by Von Höhnel (6). The genus is included by Nannfeldt (12) in the Hyaloscyphaceae. It is characterized in part by the marginal hairs, which are fastened together in toothlike fascicles.

Sepultaria arenosa (Fuck.) Boud. — On wet sand, Hulbert, Aug. 27, 1933, Mains and Smith (M. 33–521); Newberry, Aug. 30, 1933, Mains and Smith (M. 33–553).

Sepultaria pellita (Cke. & Pk.) Seaver. — In soil among mosses, Porcupine Mountains, E. B. and E. E. Mains (M. 33–647). This species was found in quantity, partly to completely buried in the soil.

Tapesia melaleucoides Rehm var. Vaccinii Rehm. — On old branches of *Vaccinium corymbosum* L., Mud Lake Bog, Whitmore Lake, May 22, 1933, Smith (33–87). This species is distinguished by the spindle-shaped spores, small apothecia, and heavy, dark brown hyphae, which form a subiculum. *T. fusca* (Pers.) Fuck. was reported on the same substratum and from the same location last year by the author (8).

Tarzetta Rapulum (? Bull.) Cke. — On rotting logs, Newberry, Aug. 31, 1933, Mains (33–566). There seems to be considerable difference of opinion concerning the disposition of specimens that have been placed in this species. Rehm (16) gives a description on page 1021. On page 823, under his treatment of the genus Sclerotinia, he places *S. Rapula* (Bull.) Rehm in the doubtful species. Nannfeldt (12) considers *Tarzetta Rapulum* (Cke.) Rehm a typonym and thereby recognizes the validity of *Sclerotinia Rapula*. There were only two specimens in our collection, but neither has a sclerotium, so that it seems illogical to refer them to the genus Sclerotinia. Having had no authentic material for comparison, the writer cannot give a critical opinion on the name to be used. All that can be stated safely is that Rehm's description of *Tarzetta Rapulum* applies to our specimens.

Trichobelonium hercynicum Lind. — On old wood, Au Train, June 6, 1933, Smith (33–15). The substratum is different from

that cited by Rehm (17) for this species, but it can scarcely be considered anything else, since the color, shape, and size of the apothecia, as well as the measurements of asci and spores, fit exactly the description of Rehm.

UNGUICULARIA SCULPOSA (Karst.) v. H. — On old wood, Au Train, June 6, 1933, Smith (33-1158). The apothecia are minute. The short, blunt, one-celled hairs on the exterior of the cups separate this genus from closely related genera in the Hyaloscyphaceae. The asci are short and wide at the base; the spores are minute, measuring 4–5 × 1.5 μ. This fungus has appeared under various names since the time of Karsten (9), but seems well placed in von Höhnel's genus. It is illustrated by Boudier (1) in plate 529.

VELUTARIA CINEROFUSCA (Schw.) Rehm. — On wood in running water, Yellow Dog River, Big Bay, June 13, 1933, Smith (33-459).

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LITERATURE CITED

1. BOUDIER, E. 1905-10. Icones Mycologicae ou Iconographie des champignons de France. Paris.

2. DURAND, E. J. 1908. The Geoglossaceae of North America. Ann. Myc., 6: 387–477, 17 pls.

3. —— 1923. The Genera Midotis, Ionomidotis and Cordierites. Proc. Am. Acad., 59: 1–18, 2 pls. (Edited with note and two plates by Roland Thaxter.)

4. HÖHNEL, F. VON. 1902. Fragmente zur Mykologie I, Mitt., Nr. 1 bis 63. Sitzb. k. Akad. Wissensch. Wien, Math.-Nat. Kl., Abt. I, Band 3, Heft 10.

5. —— 1907. Fragmente zur Mykologie III, Mitt., Nr. 92 bis 155. *Ibid.*, Abt. 1, Band 116, Heft 1.

6. —— 1918. Fragmente zur Mykologie XXII, Mitt., Nr. 1092 bis 1153. *Ibid.*, Abt. I, Band 127, Hefte 8–9.

7. —— 1926. Über die Gattung Pezizella Fuckel. Mitt. a. d. bot. Institut d. Techn. Hochsch. Wien, 3: 54–80. (Edited by J. Wesse.)

8. KANOUSE, B. B. 1935. Notes on New or Unusual Michigan Discomycetes. II. Pap. Mich. Acad. Sci., Arts and Letters, 20 (1934): 65–78.

9. KARSTEN, P. A. 1869. Monographia Pezizarum fennicarum. Not. Sallsk. F. Fl. Fenn. Forh. X.

10. Karsten, P. A. 1871. Mycol. Fennica, Pars prima. Discomycetes. Bidr. t. kännedom af Finl. nat. o. folk. 19. Helsingfors.

11. Lagarde, J. 1906. Contribution à l'étude des Discomycètes charnus. Ann. Myc., 4: 14–256, 2 pls.

12. Nannfeldt, J. A. 1932. Studien über die Morphologie und Systematik der nichtlichenisierten inoperculaten Discomyceten. Nova Acta Regiae Societatis Scientiarum Upsaliensis, Ser. IV, 8, No. 2: 1–368. Upsala.

13. Peck, C. H. 1879. Report of the Botanist. Thirty-second Rep. New York State Mus. Nat. Hist. Albany.

14. —— 1887. Additions to the Flora of the State of New York in 1883, with Remarks and Observations. Bull. New York State Mus. Nat. Hist., 1, No. 2. Albany.

15. Phillips, W. A. 1887. A Revision of the Genus Vibrissea. Trans. Linn. Soc., Sec. Ser., Bot. 2: 1–10, 2 pls.

16. Rehm, H. 1896. Die Pilze Deutschlands, Oesterreichs und der Schweiz. Rabenhorst's Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz, Abt. III, Band I. Ascomyceten: Hysteriaceen und Discomyceten. Leipzig.

17. —— 1914. Zur Kenntnis der Discomyceten Deutschlands, Deutsch-Oesterreichs und der Schweiz. II. Ber. Bay. Bot. Gesell., 14: 85–108.

18. Saccardo, P. A. 1889. Sylloge Fungorum, 8: 505.

EXPLANATION OF PLATE XIII

Fig. 1. *Apostemidium obconicum*, sp. nov. Apothecia showing the fluff of spores over the surface. Fresh condition. × 32

Fig. 2. *Apostemidium obconicum*, sp. nov. Apothecia before the ascospores have been projected. Fresh condition. × 32

Fig. 3. *Apostemidium obconicum*, sp. nov. Apothecia in a dry condition. × 11

Fig. 4. *Apostemidium vibrisseoides* (Pk.) Boud. Photograph of the type taken in a dry condition. × 11

PLATE XIII

VEGETATIVE REPRODUCTION IN *ELEOCHARIS ROSTELLATA* *

CARL D. La RUE

INTRODUCTION

ELEOCHARIS ROSTELLATA Torr. was found growing along the shore of Wycamp Lake in Emmet County, Michigan, by Professor Frank C. Gates (1) in 1929. Later he found it at O'Neil Lake not far from Wycamp Lake, and still more recently Professor J. H. Ehlers located the species along one of the so-called Twin Lakes near Black Lake in Cheboygan County. In 1930 Professor Gates pointed out to the writer its peculiar habit of producing new plants by the growth of buds at the tips of the long, stolon-like culms. This type of propagation is unique for the region and was of sufficient interest to lead to observation and experimentation with the species during four seasons of growth, the results of which are presented in this paper.

HABIT AND HABITAT

At O'Neil Lake the plants were found in a belt about three hundred meters long in the shallow water of the lake margin. Most of them were growing in the stony soil of the lake bottom, but at one end of the belt they were rooted in a floating mat of peat and sphagnum. All the plants had their bases submerged to a depth of from 15 to 30 cm. Both sterile and fruiting culms extended above the water. Many of the longer sterile ones had bent over from their own weight and had begun to sprout as soon as the tips touched the water. As the young plants had become larger, they had gradually sunk lower into the water, and the largest were resting on the bottom and beginning to root there.

At Wycamp Lake the Eleocharis plants were growing along the shore of the lake in stony soil soaked with water, but they were

* Papers from the Department of Botany of the University of Michigan, No. 552, reporting work done at the University of Michigan Biological Station.

entirely above the water line except for their roots. Here the culms which bent over rooted as soon as their tips came into contact with the soil. The rooted stems were so numerous as to make walking through the area somewhat difficult because of the looped culms which caught upon one's feet.

Gray's Manual (2) refers to *Eleocharis rostellata* as a plant of salt marshes along the Atlantic Coast and of alkaline situations inland. Since the plants were found growing in peat at O'Neil Lake intermingled with Sarracenia and other bog plants, it was at first doubted whether the substratum was alkaline, or even neutral. However, an average of three samples of water pressed out from the floating mat at O'Neil Lake gave a pH of 7.38, while three samples of the water over the roots of the plants at the same place averaged pH 7.53. Seven samples of soil from around the roots of Eleocharis at Wycamp Lake gave an average pH of 7.11.

The Effects of Submergence

In 1932 a beaver dam which closed the outlet of O'Neil Lake caused a considerable increase in the depth of the water. The Eleocharis plants were able to grow, however, and fruiting culms were numerous, as were also the long stems rooting at the tips.

In the summer of 1933 the plants were almost completely submerged and very few of the culms grew enough to extend more than a few centimeters out of the water. No fruiting branches were found, and none of the emerged tips of sterile culms were long enough to bend over. Therefore, no rooting tips were found. It was rather surprising that none of the tips under the water showed any sign of rooting.

A year later, in 1934, the beaver dam had been destroyed and the lake had fallen to its 1931 level. The growth of the Eleocharis was normal, and many long culms had been produced which bent over and rooted at the tips. However, although very few plants had been killed by their long submergence, no fruiting stalks could be found. Apparently the unfavorable conditions had prevented the formation of any flower buds.

GROWTH IN THE GREENHOUSE

Although the plant seems to be confined, under natural conditions, to lake margins and can live under partial submergence,

it can exist also with a much more limited water supply. Several plants were transferred to the greenhouse at Ann Arbor and potted in ordinary garden soil. With regular watering these plants have grown and continued to produce sterile culms continually, both in summer and in winter. The long stalks have bent over and have rooted themselves in pots of earth, and even among the cinders on the greenhouse bench.

In the greenhouse the plant is evergreen and continues its growth regularly. In nature the bases of the culms which are not destroyed by ice and frost remain green well into a second season, so that it is not surprising to find that the stems in the greenhouse are long-lived; but it might have been suspected that the buds at the stem tips would show periodicity in sprouting. However, this is not the case, for they seem to grow equally well at all seasons of the year. Still it should be noted that the greenhouse plants have never flowered, and this may be due to an uninterrupted growth.

The greenhouse plants in soil are not so robust as those growing in water, but otherwise are quite unchanged. Although the plant is not a true aquatic, it is probably unable to withstand the competition of other plants which grow more vigorously on the better-drained soils. Possibly it is unable to endure drought, but an occasional drying out of the soil in the pots in the greenhouse has not caused them any noticeable damage.

VEGETATIVE REPRODUCTION

Eleocharis rostellata develops only very short rootstocks and does not stool at the base to any considerable extent. Hence it depends largely for its spread upon the rooting of the tips of its long culms. Various trials have shown that other parts of the plant are quite incapable of regeneration, and the capacity to form buds is entirely restricted to the ends of the culms. Even here the reproduction is altogether from preformed buds, and excised buds are never replaced, so that in the strict sense the plant is incapable of any regeneration.

In nature the buds at the stem tips never begin growth until the stems become so long that they bend over and thus bring the tips into contact with the water or damp soil. Once such contact is made, growth takes place in a few days. In three days in summer a green tip appears, which turns sharply upward, and two or three roots emerge and grow downward.

The base of the young plant grows thicker and gives rise to numerous roots and to a small number of branches in addition to the single shoot which first grows out. But the number of branches from the short rootstock which is developed is never large, and further growth depends on the production of one or two branch rootstocks, and, of course, on the new plants formed at the tips of the stalks. On the wild plants none of the spike-bearing culms were rooted, and at first the presence of vegetative buds was not detected. But in the regeneration trials some of the spikes were cut off and floated in water, and others were laid on moist filter paper. After an interval of three days 10 per cent of these showed shoots like those on the sterile culms, but somewhat diminished in size. These growths developed from very inconspicuous buds at the base of the spike. None were ever found in any other part of the spike, and only one bud was found on each spike.

It was discovered by trial that the fruiting culms would always sprout if they were bent over so as to come into contact with the water or the soil, and also that sterile culms much shorter than those which had rooted would root if they were broken over in the same manner. The difference between the rooted and the unrooted culms seemed to be a matter of length. If the stems were long enough to bend over, they rooted; if not, their buds remained undeveloped. Table I shows the lengths of rooted nonfruiting, of unrooted nonfruiting, and of unrooted fruiting culms.

TABLE I

Lengths of Rooted Nonfruiting Culms, Unrooted Nonfruiting Culms, and of Unrooted Fruiting Culms

Type of culm	Range of lengths	Average length
Rooted nonfruiting	100–175 cm.	129.5 cm.
Unrooted nonfruiting	20–70 cm.	37.1 cm.
Unrooted fruiting	31–80 cm.	49.9 cm.

From Table I it appears that the culms which have not rooted are all too short to bend over, and hence have no opportunity to place their buds in the situation which they need for their development. Trials have shown that the buds on culms not more than ten centimeters long are mature and capable of growth, although they require more than twice as long to start development as those on mature shoots.

The stems show little variation in thickness and are all oblong in cross section. They average 1 × 2 mm. in their dimensions, and the fruiting culms do not vary in internal structure from the nonfruiting ones. The only difference in the two types of culms, other than that one bears fruiting spikes and the other does not, is that growth ceases in the fruiting stems long before it does in the nonfruiting ones.

The growth of the stems takes place almost entirely from a basal meristem, and in culms which are bearing fruit the basal meristem has entirely disappeared. In the sterile stems the meristem persists at the base until the end of the growing season. In stems produced late in the season the meristems may continue activity and complete their growth in the following spring.

It seems that the development of fruits has an inhibiting effect on the activity of the basal meristem. Surely the spike cannot require more water than a long sterile culm, so that the change cannot well be attributed to changed water relations. In any event the often-submerged meristems could not often lack water. As for food supply, the conditions are different. The long culms have more photosynthetic area to supply energy to their meristems, and the developing fruits on the fertile stalks may deprive the meristems at their bases of food for further activity. It is possible that the spikes develop some inhibiting substance which passes downward and causes all the cells of the meristem to mature. At present, no means seem available for distinguishing between an effect due to an inhibiting substance and one due to a diminished food supply. It would be interesting to remove the spikes from flowering plants to see whether the basal meristem would remain active. This has not been done because of the inability to visit the wild plants sufficiently early in the spring, and thus far the greenhouse plants have not fruited.

Though the fruiting spikes have not been removed experimentally, an examination of the tips of the nonfruiting culms has revealed an interesting fact. It appears that every one of the sterile culms really has an aborted flower spike in the terminal position, and that the vegetative bud arises from a lateral position below the undeveloped spike. It may be that this is not always true, but some dozens of the tips have been dissected without failing to find the aborted spike in a single specimen. It is likely, then, that

the two types of stem are identical in origin and structure, but that some develop a flower bud, and a small, somewhat suppressed vegetative bud, while the others fail to produce flowers, but give rise to a well-developed proliferative tip.

CONDITIONS FAVORABLE TO GROWTH OF BUDS

It has been stated before that the buds on the tips of erect culms do not sprout. On the other hand, the long stolons, or arched stems, root at the tips as soon as these tips come into contact with water or damp soil. Apparently, a sufficient water supply is the only requirement, for the buds will root in contact with any damp substance. Water, earth, cinders, sand, sphagnum, filter paper, and cotton have all proved satisfactory as substances for producing growth of the buds.

It is not necessary for the buds to remain attached to the culms, for they will root well when cut off with one centimeter or less of the stem attached to them.

The bending over of the culms plays no part in the outgrowth of the buds, and it is not important for the tips to be turned downward. When removed from the stems, the buds will grow equally well in a horizontal, an upright, or an inverted position.

Since the erect culms do not sprout, it might be supposed that the bending over might change the condition of the stems in some way so as to dispose them toward development. Cutting off the tips might have a similar effect in removing a flow of food, for it was found that excised buds grew at once. Tests of this hypothesis were made by binding erect tips in sphagnum which was kept moist, and by inserting tips into inverted test tubes lined with wet filter paper. Tips treated in these ways rooted as readily as though the culms had been bent over to bring the tips down to the water.

The age of the buds seems not to be of importance. Tips on culms not nearly old enough to bend over root when put into contact with a wet substance in the erect position, or when cut off and laid on such material. Very young culms, under five centimeters in length, bear buds which will grow if supplied with moisture, although their outgrowth is slower than that of buds from mature stems. Furthermore, as has been related, seed-bearing culms, which have never been observed to grow long enough to bend over, will

grow from vegetative buds at the bases of the spikes if they are cut off and laid in water, or on some moist substratum.

Tips of all ages from both sterile and fruiting culms will grow if floated on water, whether distilled, taken from the tap, or from the lake. In view of this fact, it was curious to see that the buds on plants submerged in the deep water due to the obstruction of the beaver dam at the outlet of O'Neil Lake in 1933 did not sprout, in spite of their being surrounded by water. During this season all the culms were very short, and none of them came up to the surface of the water. However, the tips had not lost their capacity for growth, for when they were cut off and floated on the surface of the water, they grew at once.

An experiment was performed to see whether lack of air in the submerged condition was the factor inhibiting growth. Tips were cut off, attached to the ends of glass rods, and sunk to the bottom of test tubes under fifteen centimeters of distilled water. One set of tubes was aërated by bubbling air through the water several times daily; another set was left unaërated. The tips in the aërated tubes grew; those submerged in unaërated water did not.

It seems clear, then, that lack of air prevented the buds from growing in O'Neil Lake in 1933, but the reason is not evident for the failure of growth of buds on plants living in shallow water, where they are often found. Such buds appear ready for growth, and as the culms grow they are carried up through the water and out into the air. Why do they not sprout when they are brought into the well-aërated surface layers of the water as they are pushed up? Possibly the answer lies in the fact that they are slow in beginning growth, and the basal development may push them through the layer of aërated surface water before they have time to sprout.

TOLERANCE OF ACID AND ALKALINE SUBSTRATA BY BUDS OF *ELEOCHARIS ROSTELLATA*

The observation that buds of Eleocharis would grow on sphagnum with an acid reaction (pH 4 ±) aroused curiosity as to what tolerance of acid conditions these buds might show. Accordingly a series of rough tests was made to determine the facts. Dilutions of 85 per cent lactic acid were made with tap water, which at the University of Michigan Biological Station is practically neutral. The acid was mixed with the water in various dilutions ranging

TABLE II

TOLERANCE OF ACIDITY BY ELEOCHARIS BUDS

No. of test	pH of solution	Development after 5 days	Development after 8 days
1	2.46	2 yellowed	All yellow and moldy
2	2.63	2 yellowed; no growth	2 normal, no growth; 3 dying
3	2.80	2 turned up at tip; 1 dead	1 has weak shoot 4 mm. long; 1 turned up at tip; 2 dormant; 1 dead
4	2.97	4 have growing shoots; 3 have roots 3 mm. long	4 have shoots 2–4 mm. long; 2 have 2 roots each; 2 have 1 root each 2–4 mm. long; 1 has no growth
5	3.13	5 have stem growth; 1 has a root	5 have stem growth; 2 have 1 root each, 4 mm. long; 3 have no roots
6	3.30	5 have stem growth; 3 have roots, 6, 3, and 3 mm. long	4 have shoots 2–4 mm. long; 1 has a very short stem; 3 have 1 root each, 5, 6, and 8 mm. long. Roots full of short sharp curves
7	3.47	All have shoot growth; 4 have roots 3–5 mm. long	All have shoots 2–6 mm. long; each has 1 root, 2, 4, 5, 6, and 7 mm. long. Roots slightly wavy
8	3.64	All have growing shoots; all have roots 4–6 mm. long	4 have shoots 3–6 mm. long; 4 have roots 4–7 mm. long; 1 bud dead
9	3.72	All have stem growth; 3 have roots	All have shoots 3–5 mm. long; 3 have roots 4–6 mm. long; others no roots
10	3.81	All have stem growth; all have roots 4–6 mm. long	All have shoots 3–5 mm. long; 1 has 2 roots, 3 and 8 mm. long; others have 1 root each 4–7 mm. long
11	3.98	All have shoots; all have roots 6–8 mm. long	All have shoots 3–5 mm. long; 1 has 2 roots, 3 and 7 mm. long; others have 1 root each, 4, 10, 12, and 15 mm. long

from one part per 100 of water to one part per 100,000 of water. In each dilution five tips of Eleocharis were floated. The experiment was performed in August, at which season detached buds normally show stem outgrowth after the lapse of three days. Notes were taken on the development of the buds in the acid solutions at five-day and eight-day intervals. The first evidence of growth is to be seen in the turning up of the tips of the buds by growth of the shoot inside which has not yet emerged from the bud scales. Hence growth can be determined before the shoot length can be

TABLE III

TOLERANCE OF ALKALINITY OF ELEOCHARIS BUDS

No. of test	% of NaOH	Results after 5 days	Results after 8 days
1	1.0	All yellowed	4 dead; 1 dying
2	0.1	3 alive; 2 have roots 5 mm. long; 2 dead	1 has a shoot 4 mm. long; 2 have very short stems; 1 has a root 11 mm. long; 1 has 3 roots, 1, 3, and 12 mm. long
3	0.02	All have shoots; 4 have roots 1–2 mm. long.	5 have shoots 1–4 mm. long; 3 have roots 1–4 mm. long; 1 has 2 roots 3 and 7 mm. long
4	0.01	All have shoots; all have roots 1–15 mm. long	All have shoots 3–5 mm. long; 4 have roots 2–5 mm. long; 1 has a root 18 mm. long
5	0.004	4 have shoots; 2 have short roots	4 have shoots 1–3 mm. long; one has a very short shoot; 2 have roots, 2 and 4 mm. long
6	0.002	4 have shoots; 2 have very short roots	All have shoots 2–4 mm. long; 1 has 2 roots, 2 and 4 mm. long; 1 has 3 roots, 2, 3, and 5 mm. long; others have no roots
7	0.001	4 have shoots; 2 have roots 12 and 15 mm. long	All have shoots 1–4 mm. long; 3 have roots 4, 12, and 15 mm. long; the others have no roots
8	0.0004	All have shoots; 4 have roots, 5, 6, 8, and 9 mm. long	All have shoots 2–5 mm. long; all have roots, 3, 6, 9, 10, and 12 mm. long

measured. The results of this experiment are given in Table II. Determinations of pH were made with the Youden quinhydrone apparatus, and also with color indicators.

From Table II it might be assumed that the buds require acidity for their development, as do the embryos of some seeds, but the regeneration experiments already performed proved that the buds were capable of growing in neutral tap water, and on filter paper moistened with neutral tap water or with distilled water. But to determine whether growth was possible in alkaline as well as neutral solutions another series of tests was run. Dilutions of NaOH were made with tap water, which was practically neutral, ranging from 1.0 per cent to 0.0004 per cent. Five normal tips of *Eleocharis rostellata* were floated in each of the solutions, and observations were made on them at five-day and eight-day intervals, as in the

preceding experiment. The pH of all these solutions was found to be above 9.0 and beyond the range of both the quinhydrone apparatus and our colorimetric equipment. Hence the results were tabulated with percentages of NaOH instead of pH determinations. This experiment, like that on acid tolerance, is rather rough, and a failure of growth in all the buds might have been attributed to toxicity of the solutions, but the development of shoots in all except exceedingly alkaline solutions seems to show that these solutions were not toxic or, at most, not sufficiently so as to vitiate the experiment. Table III presents the data from this test.

It is clear from the results given in Table III that the buds of Eleocharis do not require acidity for their development, but can develop under very alkaline conditions also. The ability of these buds to grow in solutions of such highly variable hydrogen-ion concentrations is remarkable.

TRIALS OF SEED GERMINATION

Although *Eleocharis rostellata* depends for its local spread on vegetative propagation, its wider introduction must depend upon its seeds. Each fruiting spike develops from three to twelve achenes, which appear to be normal. They have an abundant endosperm and a small embryo, but thus far they have not been seen to germinate. Careful search for several seasons in the territory where thousands of seeds are produced annually has not revealed a single seedling. Seeds were collected in 1931, 1932, and 1933. In 1933 no seeds were produced at O'Neil Lake because of the depth of the water, and in 1934, although the water had fallen to its normal level and vegetative growth was vigorous, no flowers or fruits were found. A collection of seeds was secured from Wycamp Lake in 1933, but this vicinity was not visited in 1934, and no seeds were obtained.

Numerous germination trials were made with seeds in 1931, 1932, and 1933. Seeds were planted on earth in pots, and on moist filter paper in Petri dishes. Some were kept in light, others in darkness. Seeds of 1931 and 1932 were subjected to repeated freezing and thawing. In other tests the achenes were pricked with the tip of a needle. All attempts that have been made have met with complete failure.

In 1934 another series of tests was made, as shown in Table IV.

TABLE IV

GERMINATION TRIALS WITH SEEDS OF *ELEOCHARIS ROSTELLATA* IN 1934

Number of trial	Year of seed production	Number of seeds	Treatment	Germination after two months' trial
1	1933	50	Floated on water, in light	0
2	1933	50	" " " in dark	0
3	1933	50	On wet paper, in light	0
4	1933	50	" " " in dark	0
5	1932	50	" " " in light	0
6	1932	50	" " " in dark	0
7	1933	50	On earth, in light	0
8	1933	50	" " in dark	0
9	1933	25	Pricked, on wet paper, in light	0
10	1933	25	" " " " in dark	0
11	1932	25	" " " " in light	0
12	1932	25	" " " " in dark	0
13	1933	50	Under water exhausted with aspirator, then air admitted and seeds kept under water	0
14	1933	50	Treated 10 minutes with concentrated sulphuric acid, then washed and kept under water in light	0
15	1933	50	As for preceding, but in dark	0

The distribution of *Eleocharis rostellata* indicates the probability that the seeds have been the means of dispersal. The culms, to which the young vegetatively propagated plants are attached, usually do not rot away until the plants are too large for effective dispersal by birds, the most probable carrier. It would be premature to assume that the seeds are incapable of germination, but the conditions under which they may grow have not been discovered.

DISCUSSION

The interest of this study lies chiefly in the fact that the type of vegetative propagation found in *Eleocharis rostellata* is unique in this region. The Cyperaceae and the Juncaceae abound in species which bear slender culms tipped with inflorescences, but no other representative of the region has the ability to produce new plants from the tips of the stems. It is true that *Eleocharis*

melanocarpa Torr., *Juncus pelocarpus* Mey., *J. subtilis* Mey., and *J. bulbosus* L. are reported as producers of similar vegetative buds, but none of these are found in the territory adjacent to the University of Michigan Biological Station. In general, this form of reproduction is not common among the Monocotyledoneae. Such plants as *Marica gracilis* Herb. and *Chlorophytum elatum* R. Br. are commonly known examples of such reproduction, and the latter forms young plants abundantly on its inflorescences without contact with the soil. But both these plants are native to regions more favorable for such types of propagation than ours.

Eleocharis rostellata represents a type of plant which is specialized in its vegetative propagation. In general, the Monocotyledoneae are specialized in this respect. Though a host of species can be propagated vegetatively, nearly all of these have one method, and only one, by which they may be multiplied, and in these forms proliferation takes place only from preformed buds. The capacity to regenerate new buds from various organs of the plant is rare among the Monocotyledoneae. *Sansieveria zeylanica* Willd. is a species which has true regenerative ability, and it readily forms new roots and shoots from any portion of its leaves. On the other hand, so notorious a weed as quack grass, *Agropyron repens* (L.) Beauv., which sprouts readily from any single node of its rootstock, has no power whatsoever to regenerate new buds. *Eleocharis rostellata* is consistent in its behavior with the great majority of the species of its family.

Gray's Manual (2) reports *Eleocharis rostellata* as a plant occurring in "salt marshes, N. H. to Fla., and locally in alkaline situations inland." The tests of the hydrogen-ion concentration of its Michigan habitats show that these are slightly alkaline. Therefore, it is surprising to find the young plants produced by the culm tips so tolerant of acid conditions. This tolerance must be lost as the plants develop. Further studies are planned to determine the age at which this change takes place.

SUMMARY

1. *Eleocharis rostellata* Torr. has been found in three localities in the northern end of the Southern Peninsula of Michigan.

2. The habitat of the plant in these localities is slightly alkaline in reaction.

3. Vegetative reproduction by the growth of buds at the tips of the culms is the means of local spread of the plant.

4. The tip buds will grow under a wide variety of conditions, and are remarkably tolerant of acidity of substratum.

5. Each of the culm tips produces a flower bud and a vegetative bud. In fruiting culms the vegetative bud is suppressed, but capable of growth. In the greater number of culms the flower bud is abortive, and the vegetative bud develops.

6. The elongation of the culm is due mainly to the growth of a basal meristem, which is inhibited by the development of the flower bud. Hence the nonflowering culms grow to a much greater length than do the flowering ones, and finally bend over from their own weight, so that their tips are brought down to the water, or damp earth, where they can grow.

7. The two types of culms are identical in internal structure.

8. Germination trials of the seeds have been entirely unsuccessful, and no seedlings have been found in nature.

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LITERATURE CITED

1. Gates, F. C., and Ehlers, J. H. 1931. Additions to an Annotated List of the Higher Plants of the Region of Douglas Lake, Michigan. II. Pap. Mich. Acad. Sci., Arts and Letters, 13 (1930): 67–88.

2. Gray, Asa, and Others. 1908. Gray's New Manual of Botany, Seventh Edition, 926 pages.

ON THE LICHEN FLORA OF NORTHERN MICHIGAN *

JOSIAH L. LOWE

THE lichen flora of Michigan, as would be expected, is very similar to that of Minnesota as reported by Fink (5), and roughly parallel to that reported from the North Atlantic States, though less numerous. It is known chiefly from Nichols' list (10) of 155 species and varieties from the northern part of the Lower Peninsula; from the collections of Darlington (2) and E. A. Bessey (unpublished) from the Porcupine Mountains, numbering about 60 species; from Dachnowski's (1) and Ruthven's (11) reports of a few species found in the Upper Peninsula; and from a collection of over 290 species and varieties made by the author (7) on Isle Royale in 1931, while a member of the University of Michigan botanical party.

Except for a few additions from the Isle Royale collections, the following notes are based upon a part of some twelve hundred collections of lichens made in the region of Munising and Marquette during June, 1933. During this time the writer was a guest of Dr. and Mrs. E. B. Mains, and he is further indebted to Dr. Mains for a critical reading of this manuscript. The fruticose and foliose material and a very small portion of the crustose material have been identified to date, some 447 collections comprising 188 species and varieties. The remainder of the crustose material is being worked over, and the determinations will be reported later.

The habitats collected over intensively were the burns and the shore-line rocks. The burns, such as those at Rock River, are of the type common in upper Michigan, consisting mostly of a scattered growth of popple and other small trees, with a rather sparse ground cover. The shore-line flora was studied carefully at Laughing Whitefish Point near Deerton and at the Sugarloaf Mountains

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 543.

near Marquette. Laughing Whitefish Point is low and rocky, and extends into Lake Superior about one-half mile from the general shore line. The best collecting was found on the western side. At the tip the shore slopes gradually from the water level, but farther back the shore rises abruptly, with cliffs from ten to fifteen feet high. The Sugarloaf Mountains rise abruptly to a height of about five hundred feet above the shore, and the lichen flora of the rocks near the top and facing the lake, and on the sides of the gullies running toward it, was especially interesting and varied.

GEOGRAPHIC DISTRIBUTION

Although only a few scattered areas in the northern United States have been collected over intensively enough to afford an adequate basis for a study of lichen distribution, an attempt at such a study may be of interest. It might be supposed that the new records of lichens for Michigan would be western extensions of the range of lichens known from the northeastern states. Curiously, however, the writer's collections contain a greater number of species known from the Atlantic and the Rocky Mountain and the Pacific Coast States, with the Michigan records the only known intermediate station. Northern Michigan thus appears to be within the plant zone connecting the eastern and the western lichen floras. Northern and eastern extensions of range are much less common. In this account only the writer's collections are enumerated. If the records of Nichols (10) and especially those of Fink (6) were included, a much larger list of species could be made.

Haematomma cismonicum and *Physcia lithotea* were known previously from the Atlantic Coast States, and their record from Michigan constitutes a decided western extension. *Solorina saccata spongiosa* was known to occur on the Atlantic Coast and in the Rocky Mountain or Pacific Coast States, and its record here constitutes the only known intermediate station. The record for *Anaptychia leucomelaena* is a northern extension of range; *Lecidea fuscescens* is here a record of eastern extension of range. Also the record of *Cladonia cornuta phyllotoca* appears to be the first valid one for North America.

NOTEWORTHY SPECIES FROM MICHIGAN

With the exception of *Physcia virella*, *Lopadium pezizoideum*, *Parmeliopsis pallescens*, and *Stenocybe major*, all the following

records are new for Michigan. Distribution notes are given only if Michigan lies outside the previously recognized geographical range of the species. These notes are taken from Fink (6) or Tuckerman (12) or Zahlbruckner (15). The nomenclature in Zahlbruckner's catalogue (15) is followed.

Anaptychia fusca (Huds.) Vain. — On cedar along the shore of Au Train Lake. Sterile and scarcely typical.

Anaptychia leucomelaena (HBK.) Vain. — Northern extensions of lichen distribution are rather unusual, and so the record of this typically much more southern species on branches on a wind-swept shore of Au Train Lake is of considerable interest. The plant was sterile, but typical in all other respects. It had been known from New York (Peck, one collection) south to North Carolina, westward to Louisiana and north to Ohio (Lea, one collection), and in California.

Calicium lenticulare sphaerocephalum (Hoffm.) Zahl. — On conifer stub along the shore of Laughing Whitefish Point.

Calicium floerkei Zahl. — On stumps, Laughing Whitefish Point and at Onota. No algal host is present, and this species is referred to *Embolidium Italicum* Sacc. by Vainio (14).

Caloplaca murorum (Hoffm.) T. Fries. — On shore rocks, Sugarloaf Mountains.

Chaenotheca brunneola (Ach.) Müll. Arg. — On cedar logs at Wagner's Falls near Munising.

Chaenotheca trichialis (Ach.) Hellb. — On cedar at Rock River and below Wagner's Falls near Munising.

Cladonia caespiticia (Pers.) Floerke. — On moss over shore rocks, Rock River. *C. caespiticia plumosa* is reported from Carp Creek by Nichols (10).

Cladonia cornuta phyllotoca (Floerke) Arn. — Occurring with the species but less common, now well marked, with abundant squamules, now merging with the species, the squamules few. This variety does not appear to have been reported from North America. The species *C. cornuta* (L.) Schaer. is common on soil and old stumps in burns in upper Michigan.

Cladonia crispata virgata (Ach.) Vain. — On sandy soil along the Lake Superior shore at Au Train. The writer knows of no definite report of this variety for the United States, but Fink (6) places it in synonymy with the species.

Cladonia degenerans polypaea (Ach.) Vain. — On soil in burn, Rock River. The material does not agree very well with Sandstede Exsiccatae Nos. 1553, 1554, 1555, 1732, but agrees exactly with Vainio's description: "Podetiis squamosis a f. *dilacerata* differt" (13, p. 97). The variety does not appear to have been reported from the United States.

Cladonia fimbriata nemoxyna (Ach.) Coem. — On soil in burn, Bald Mountain near Big Bay.

Cladonia macilenta squamigera Vain. — On soil over rocks, Sugarloaf Mountains near Marquette. Known also from Connecticut.

Cladonia pyxidata pocillum (Ach.) Flot. — On sandy soil on the Lake Superior shore at Au Train. The squamules are rather thin for this variety, but the characters of these specimens compare better with those of var. *pocillum* than of var. *neglecta* (Flk.) Mass.

Cladonia subcrispata (Nyl.) Vain. — On soil over rock at Chatham and at Laughing Whitefish Point. This species is very close to *C. furcata paradoxa* and is easily confused with it. The writer made his determinations by comparison with Sandstede Exsiccatae Nos. 665, 666. Vainio (13, p. 52) discusses this species under *C. furcata paradoxa* and says of it:

> "A var. *paradoxa* distinguenda est *Cl. subcrispata* (Nyl.) Vain. . . ., quae inter duas species, in diversas sectiones pertinentes, *Cl. furcatam* et *Cl. pityream*, est intermedia et habitu quasi hybrida, a praecedente podetiis typice scyphiferis et scyphis membrana integra aut perforata clausis et parietibus podetiorum tenuioribus, a posteriore apotheciis parvis et apicibus podetiorum fertilium subcorymbose ramulosis."

The species has usually been treated in American lichenological literature under the name *C. multiformis*, but there appears to be no valid reason why the earlier name *subcrispata* should not be used instead. Evans (4, p. 428) separates related species from *C. multiformis* as follows:

> "Its most distinctive features are found in its cups, which can usually be demonstrated without difficulty and which are often abundantly produced. These cups are broad and conspicuous and are closed by membranes that are radially lacerate or minutely punctured in various ways. No other species of

Cladonia, so far as known, has closing membranes of precisely this character, although the membranes of the poorly developed cups in *C. turgida* resemble them to a certain extent."

Collema furvum (Ach.) DC. — On shore rocks, Sugarloaf Mountains.

Coniocybe furfuracea (L.) Ach. — Common on bark and soil about upturned roots.

Haematomma cismonicum Beltram. — On pine in a swamp on Laughing Whitefish Point. Known also from New England, New York, and North Carolina.

Lecanora cancriformis (Hoffm.) Vain. — On maple in swamp, Laughing Whitefish Point.

Lecanora polytropa (Ehrht.) Rabenh. — On shore rocks, Sugarloaf Mountains.

Lecidea fuscescens Sommerf. — On old twigs in a bog, Isle Royale, and subsequently collected in the Adirondacks, New York State, by the writer. Previously known from the Santa Monica Mountains of California. This is the only certain and important eastern extension of the known range of the species treated here. *L. fuscescens* is closely related to *L. Nylanderi* and, in specimens with a well-developed thallus, can be separated by the granulose-leprose condition of the thallus in *L. Nylanderi*, as contrasted with the thin, determinate thallus composed of minute granules in *L. fuscescens*.

Lopadium pezizoideum (Ach.) Koerb. — On bark, Wagner's Falls near Munising and on Isle Royale. Known also from Massachusetts, New York (where it is common in the Adirondacks), Florida, and Washington.

Pannaria leucosticta Tuck. — On rocks at Laughing Whitefish Point, at Bald Mountain near Big Bay, and at Sugarloaf Mountains.

Pannaria rubiginosa lanuginosa (Hoffm.) Zahl. — On moss over rock at Sugarloaf Mountains near Marquette.

Parmelia centrifuga (L.) Ach. — On exposed rocks facing the lake shore, Sugarloaf Mountains. When first seen, it may be confused with *P. conspersa*, but when once known it is easily distinguished from it. In *P. centrifuga*, especially in old specimens, the center often disappears, leaving a band of outward-growing thallus.

Parmelia pertusa (Schrank) Schaer. — On trees, Au Train Lake.

Parmeliopsis pallescens (Neck.) Zahl. — On old wood, Au Train, Bald Mountain near Big Bay, and Isle Royale. Known also from Connecticut, New York, and Pennsylvania.

Physcia caesia (Hoffm.) Hampe. — On beech tree, Au Train. Sterile.

Physcia lithotea (Ach.) Nyl. — This species and its var. *lithotodes* have been reported from Maine by Merrill (9), but only the latter record is credited by Fink (6), under the name *P. lithotodes* Nyl. The Michigan material, abundant along the shore at Laughing Whitefish Point, is densely isidioid, and there can be no doubt as to its identity, since this species is most readily separated from the variety by the greater development of the isidia. Lynge (8) lists, in addition to the isidia characters given in his key, still others under his description of the variety:

> "Separated from *Physcia lithotea* by the paler colour (?) which seems to be normal in var. *lithotodes*, by convex laciniae and by the placodium-like thallus. The upper cortex is thinner than in *Ph. lithotea* and the green colour more visible in moistened plants. The disposition to form isidia is very weak, but not quite absent."

Physcia teretiuscula (Ach.) Lynge. — On rocks, Laughing Whitefish Point, and a somewhat doubtful collection from Bald Mountain near Big Bay. Known from Minnesota, Iowa, and North Dakota, and recently collected in the Adirondacks, New York State, by the author.

Physcia virella (Ach.) Flagey. — The distribution of this species in the United States is quite uncertain. Merrill has specimens from Maine, Merrill Exsiccati No. 150, and has so determined a specimen from Michigan (10), but his records and Evans' record from Connecticut (3) (both as *P. obscura virella*) are not recognized by Fink (6). He reports this species from Michigan only (herbarium specimen from Mackinac Island), but states: ". . . no doubt more widely distributed, but no other specimens studied belong here." The writer has collected this species on Isle Royale and in the Upper Peninsula near Onota, Au Train Falls near Au Train, along Au Train Lake, and in the Adiron-

dacks in New York State. Since it is inconspicuous and usually sterile, no doubt it has been passed over by collectors. The color of the soredia is uniformly light green, and no specimens were found that showed the range described by Lynge (8, p. 73): "Soredia greyish white, greyish green or occasionally yellowish." In other respects the material agrees very well with his description. The Onota and Au Train Falls specimens were fertile.

Solorina saccata spongiosa (Sw.) Nyl. — A northern Michigan station for this rare plant is of unusual interest. Previously it had been known from Labrador, Colorado, and Washington. The plant grew on moss continually wet by driving spray at the base of Miner's Falls near Munising, intermixed with *S. saccata*. It is distinguished from the latter by the scanty development of the thallus, in these specimens restricted to a narrow collar up to 2 mm. broad around the large apothecia.

Stenocybe major Nyl. — Apothecia stalked, 0.6–1 mm. high, KOH −, the stipe unbranched or rarely one-branched, black and shining, slender, 0.03–0.06 mm. in diameter, nearly equal throughout, composed of parallel agglutinated hyphae; head narrow club-shaped or in the largest apothecia often top-shaped and compressed, greatest diameter 0.1–0.2 mm., the disk typically black, sometimes depressed, more often plane to convex; within hypothecium light brown, of erect agglutinated hyphae, changing gradually into the brownish hymenium; mazaedium not formed; paraphyses numerous, unbranched, indistinct, 1–1.5 μ in diameter below, uniform or the tip club-shaped and 2–2.5 μ in diameter; asci elongated, 150–180 × 7–10 μ; spores soon brown, 3-septate, oblong to oblong-ellipsoid, 18–35 × 6–9 μ.

This inconspicuous species is reported from New York and Washington, and has been collected at two stations in Michigan, Isle Royale and along Au Train Lake, Au Train. It is probably frequent in the northern United States and lower Canada, but is missed on account of its small size. It is rather common on smooth bark of balsams growing along openings in the forest in the Adirondacks of New York State.

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LITERATURE CITED

1. Dachnowski, A. 1907. Flora of the Marquette Quadrangle. Rep. Mich. Acad. Sci., 9: 88–103.
2. Darlington, H. T. 1931. Vegetation of the Porcupine Mountains, Northern Michigan. Part I, Ecology. Pap. Mich. Acad. Sci., Arts and Letters, 13 (1930): 9–66.
3. Evans, A. W. 1927. Notes on Connecticut Lichens. Rhodora, 29: 97–105.
4. —— 1930. The Cladoniae of Connecticut. Trans. Conn. Acad. Arts and Sci., 30: 357–510.
5. Fink, Bruce. 1910. The Lichens of Minnesota. Contrib. U. S. Nat. Herb., Vol. 14, Part 1.
6. —— 1935. The Lichen Flora of the United States. Completed for publication by Joyce Hedrick. University of Michigan Press. 426 pages.
7. Hedrick, J., and Lowe, J. L. 1936. Lichens of Isle Royale, Lake Superior. Bryologist. (*In press.*)
8. Lynge, B. 1916. A Monograph of the Norwegian Physciaceae. Videns. Skrifter, I, Mat.-Naturv. Klasse, No. 8.
9. Merrill, G. K. 1914. Noteworthy Lichens from Maine. II. Bryologist, 17: 55–58, 76–79.
10. Nichols, G. E. 1925. Lichens of the Douglas Lake Region, Michigan. Bryologist, 28: 52–59.
11. Ruthven, A. G. 1906. Notes on the Plants of the Porcupine Mountains and Isle Royale, Michigan. Geol. Surv. Mich., Ann. Rep. for 1905, pp. 75–76.
12. Tuckerman, E. 1882–88. A Synopsis of the North American Lichens.
13. Vainio, E. A. 1922. Lichenographia Fennica II. Baeomyceae et Lecideales. Acta Soc. pro Fauna et Flora Fennica, 53^1: 1–340.
14. —— 1927. Lichenographia Fennica III. Coniocarpeae. *Ibid.*, 57^1: 1–138.
15. Zahlbruckner, A. 1922–34. Catalogus lichenum universalis, Vols. 1–9.

A NEW SPECIES OF ALLENROLFEA FROM MEXICO *

CYRUS LONGWORTH LUNDELL

THE 1934 University of Michigan botanical expedition to Mexico established headquarters at Charcas in the state of San Luis Potosi from June to August. On one of the collecting excursions a visit was made to the salty lake at Santo Domingo, a village about forty miles west of Charcas. Among the interesting plants encountered on the dunes there was a halophytic sand-binding shrub, which proves to be a new species of Allenrolfea (Pl. XIV). Heretofore this genus has been represented by only a single species in North America.

Allenrolfea mexicana, sp. nov. — Frutex usque ad 2 m. altus; cortex leviter sulcatus, aliquantum fibratus, frustatus, pallide griseus; liber fulvus; lignum recens aliquantum viride, medulla viridis et continua; lignum pristinum rubicundum vel pullum; rami diffusi, alterni, lignei, nec vestigia nodorum ramusculorum carnosorum nec vestigia foliorum proponentes; ramusculi carnosi viridesque articulati; internodia 3–4 mm. crassa, 2–8 mm. longa cum vestigiis foliorum late triangularibus, amplexicaulibus, obtusis vel acutis; spicae multae, sessiles, cylindricae, 3–4 mm. crassae, usque ad 6 cm. longae; bracteae virides, carnosae vel spongiosae, rhomboideae vel aliquantum triangulares, subsessiles; flores bisexuales, tortuose dispositi, in axillis bractearum summarum 1–3, in axillis bractearum infimarum 3–7, multum conferti, aliquantum exserti; calyx in quattuor partibus divisus; tepala spongiosa, concava, carinata, imbricata, basi leviter coniuncta, fructum cingentia; stamina duo cum filamentis planis, antherae exsertae; stigmata duo, raro tria, circa 1 mm. longa, divaricata, papillosa, stili coniuncti et cum pericarpo vesiculoso pellucido membranaceo se con-

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 546.

iungentes; bases stigmatum et stili persistentes, brunnescentes, permanentes exsertae; semen brunneum, erectum, oblongum, liberum, longitudine 1 mm. paulo excedens.

A shrub not more than 2 meters high; bark finely furrowed, somewhat fibrous, shreddy, light gray, inner bark tan; sapwood greenish, pith green and continuous; heartwood reddish to dark gray; branches diffuse, alternate, woody, showing no traces of joints of the fleshy branchlets or of leaf vestiges; branchlets fleshy and green, jointed, internodes 3 to 4 mm. thick, 2 to 8 mm. long, with broadly triangular, amplexicaul, obtuse to acute leaf vestiges; flower spikes numerous, sessile, cylindrical, 3 to 4 mm. thick, as much as 6 cm. long; bracts green, fleshy or spongy, rhomboidal to somewhat triangular, subsessile; flowers perfect, arranged spirally, one to three in axils of apical bracts, three to seven in axils of basal bracts, very crowded, somewhat exserted; calyx of four spongy, concave, carinate, imbricated sepals, united slightly at base, enclosing fruit; stamens two with flat filaments; anthers exserted at anthesis; stigmas two, rarely three, each about 1 mm. long, divergent, papillose; styles united merging into the bladder-like, transparent, membranaceous pericarp; bases of stigmas and the style persistent becoming reddish brown, remaining exserted; seed reddish brown, erect, oblong, free, slightly exceeding 1 mm. in length.

Type in the Herbarium of the University of Michigan, *C. L. Lundell* 5603, collected on the sand dunes of the salt lake at Santo Domingo, San Luis Potosi, August 7, 1934. Cotype deposited in the United States National Herbarium, Washington, D.C.

Allenrolfea mexicana differs from *A. occidentalis* (S. Wats.) Kuntze, the Utah form, in being distinctly larger. The woody stem of *A. mexicana* may exceed 2 cm. in diameter; the flowering spikes are as much as 6 cm. long; and the flowers are regularly 1–3 in the axils of the apical bracts and 3–7 in the axils of basal bracts. In *A. mexicana* the time of anthesis varies from the apex to the base of the spike, and from the center of the flower aggregate in each axil toward the extremities.

Allenrolfea occidentalis is a smaller form, generally woody only at the base. It has three flowers in the axil of each bract, all of which apparently reach anthesis at about the same time.

University of Michigan

Allenrolfea mexicana Lundell, sp. nov.

HOST SPECIALIZATION OF *UROMYCES TRIFOLII* *

EDWIN B. MAINS

IN HIS *Manual of the Rusts in United States and Canada* Arthur (1) recognizes three varieties of *Uromyces Trifolii* (Hedw. f.) Lév. These are separated by their host specialization and certain morphologic distinctions. The aecia of the variety *Trifolii-repentis* are described as common, the germ pores of the urediniospores, 2–4, equatorial, and *Trifolium incarnatum* and *T. repens* are listed as hosts. The aecia of the varieties *hybridi* and *fallens* are given as rare, and the germ pores of the urediniospores of *hybridi* are reported as 2–4, equatorial, and of *fallens* as 4–7, usually scattered. *Trifolium hybridum* is listed as a host for var. *hybridi*, and *T. incarnatum*, *T. medium*, and *T. pratense* are given as hosts for var. *fallens*.

These varieties have also been recognized as distinct species. Liro (4) has pointed out the morphologic distinctions of the rust of *Trifolium repens*. He found by cultures that it would not infect *T. hybridum* or *T. pratense*. He considers it a distinct species under the name *Uromyces Trifolii-repentis* (Cast.) Liro. Paul (6) has separated the rust of *T. hybridum* under the name *Uromyces Trifolii-hybridi* Paul. Davis (2), as a result of his study of the morphology and the host specialization of the rust of *T. hybridum*, reached a similar conclusion, describing it under the name *Uromyces hybridi* Davis. In this paper the species concept employed by Arthur will be followed.

The host specialization of *Uromyces Trifolii* has been studied by Liro (4), Davis (2), and Kobel (3). Liro obtained negative results when rust from *Trifolium repens* was used to inoculate *T. hybridum* and *T. pratense*, and when rust from *T. pratense* was sown on *T. repens*. Davis reports negative results on *T. pratense*

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and *T. hybridum* from *T. repens;* on *T. repens* and *T. pratense* from *T. hybridum;* on *T. repens* and *T. hybridum* from *T. pratense.* Kobel has made the most extensive study. For the rust from *Trifolium repens* he reports positive results for *T. hybridum, T. pallescens, T. repens, T. Thalii, T. montanum, T. alpinum, T. fragiferum, T. tumens, T. incarnatum, T. rubens, T. alpestre, T. angustifolium, T. armenium,* and *T. alexandrinum,* and negative for *T. pratense* and *T. medium.* Although he reports positive results for *T. hybridum,* it is to be noted that of the six plants inoculated only one was infected. For the rust from *Trifolium hybridum* he gives positive results for *T. hybridum, T. pallescens, T. Thalii, T. montanum, T. glomeratum, T. alpinum, T. fragiferum, T. arvense, T. incarnatum, T. rubens, T. angustifolium, T. ochroleucum, T. maritimum,* and *T. squarrosum,* and negative for *T. repens, T. pratense, T. medium, T. alpestre,* and *T. pannonicum.* For the rust from *Trifolium pratense* positive results are reported for *T. Thalii, T. alpinum, T. arvense, T. pratense, T. rubens, T. alpestre, T. angustifolium, T. pannonicum,* and *T. squarrosum,* and negative for *T. hybridum, T. repens, T. montanum, T. fragiferum, T. medium,* and *T. ochroleucum.* Kobel has also shown that rust from *Trifolium ochroleucum* is distinct in its host specialization. He gives positive results for this rust for *T. alpinum, T. arvense, T. ochroleucum, T. pannonicum, T. maritimum,* and *T. squarrosum,* and negative for *T. hybridum, T. repens, T. pratense,* and *T. medium.* The rusts from *Trifolium pratense* and *T. ochroleucum* are considered specialized forms of *Uromyces Trifolii* and those of *T. repens* and *T. hybridum* species, *Uromyces Trifolii-repentis* and *U. Trifolii-hybridi.*

The studies reported in this paper were started in 1923 in the Botanical Department of the Purdue University Agricultural Experiment Station. As opportunities permitted, various collections of the clover rusts in the vicinity of Lafayette, Indiana, were studied. Since 1930 the investigation has been continued at the University of Michigan with rust collected in the vicinity of Ann Arbor. Through the kindness of Dr. A. J. Pieters, of the Office of Forage Crops of the United States Department of Agriculture, seed of a number of species of Trifolium was made available for the study. Collections were also obtained from various botanical gardens.

Cultures of the rusts were maintained on susceptible plants of the species from which they were collected. Inoculations were

made in greenhouses during the period from November to May. When several cultures were studied during the same period, they were placed in separate compartments of the greenhouse. Plants were raised from seed and usually were inoculated when a number of leaves (six or more) had developed. Spores were dusted on the plants to be tested by shaking abundantly rusted plants over them. They were then atomized with water and covered for 24 to 48 hours with wet muslin. Notes were taken when infection had reached its maximum development. The number of seedlings of a species varied with the number of different collections of seed, the amount of seed available, and the collections of rust investigated. At least 10 seedlings were available for an inoculation and usually 25 to 30 were employed. When a number of lots of seed of a species were available, as of *Trifolium pratense*, *T. hybridum*, and *T. repens*, the total number of plants for the species was often several hundred. In order to conserve space the results are given in Table I. The reactions are recorded according to type and degree of infection, as follows:

0. No uredinia; no macroscopic evidence of infection or only flecks; occasionally large necrotic spots (noted by symbol, *k*).
1. Uredinia few, small, sometimes accompanied by necrosis (*k*).
2. Uredinia fairly abundant, small, sometimes accompanied by necrosis (*k*).
3. Uredinia abundant, of moderate size, occasionally accompanied by chlorosis.
4. Uredinia abundant, large, plants evidently very susceptible.

In most instances the inoculated plants showed very little variation in reaction. A few collections, however, produced plants with marked differences. The range of reaction has been given in the table. In a few species different lots of seed produced plants having markedly different reaction. In the table the results are listed separately.

Rust from *Trifolium pratense*

As shown in Table I, *Trifolium armenium*, *T. incarnatum*, and *T. pannonicum* manifested a considerable variation in reaction to the red clover rust. Although most of the plants inoculated were more or less resistant, a few were moderately susceptible. The reverse was true for *T. pratense*. Eight different lots of seed of the latter species were employed. The results obtained agree with those previously reported (5). The majority of the plants from

TABLE I

REACTION OF VARIOUS SPECIES OF TRIFOLIUM TO RUST, *UROMYCES TRIFOLII*

SPECIES	REACTION TO RUST FROM				
	T. pratense		T. hybridum		T. repens
	Ind.*	Mich.†	Ind.‡	Mich.†	Ind.‡
T. agrarium L.	0	0	0	0	0
T. alexandrinum L.	0–1k	0–1k	1–2k	0–1k	2k
T. alpestre L.	0	0	0	0	0
T. angustifolium L.	...	0k	4	4	0
T. angustifolium L.	...	0k	...	0k	...
T. armenium Willd.	0–3	0	0–1k	0	0
T. armenium Willd.	0	0	3	...	0
T. arvense L.	0	0	3	...	0
T. carolinianum Michx.	0	0	0	0	0
T. dubium Sibth.	0	0	0	0	0
T. elegans Savi.	0	0	...	2	0
T. fragiferum L.	0	0	1k	0k	0
T. glomeratum L.	0	0	1k	0–1k	3–4
T. hybridum L.	0	0	4	4	0
T. incarnatum L.	0–3	1–2	1–2	0	0–3
T. Lupinaster L.	...	0	...	0	...
T. medium L.	0	0	0	0	0
T. montanum L.	...	0	...	0	0
T. ochroleucum Huds.	0	...	0k	...	0
T. pannonicum Jacq.	0–3	0–2	0	0	0
T. parviflorum Ehrh.	0	0	1k	0–1k	3
T. pratense L.	4(0–2) §	4(0–2) §	0	0	0
T. procumbens L.	0	0	0	0	0
T. reflexum L.	0	0	...	0	0
T. repens L.	0	0	0	0	4(0–2) §
T. repens L.	0	...	0	...	0
T. repens L.	0	...	0	...	0–2
T. resupinatum L.	...	0–1	...	0–1	4
T. resupinatum L.	...	0	...	0	0
T. rubens L.	0	0	0k	0	0
T. squarrosum Bieb.	1k	1–2k	2k	0–2k	0–1k
T. subterraneanum L.	0–1k	1k	1–2k	0k	0k
T. subterraneanum L.	1	1	3	3	0

* Results from four collections.

† Results from one collection.

‡ Results from two collections.

§ Most of the plants gave a reaction of 4. A few reacted as indicated in the parentheses.

each lot were susceptible. A small proportion were more or less resistant, some showing little or no signs of infection. From the various lots, 207 of the most resistant plants were selected and self-pollinated. *Trifolium pratense* is mostly self-sterile, and only a small amount of seed was obtained. Very susceptible as well as very resistant plants were produced from this seed, which indicates that resistance is probably a dominant character. On account of the difficulties involved it was necessary to abandon this phase of the study.

Fewer species developed uredinia in this study than in the one reported by Kobel, who obtained positive results for *Trifolium arvense, T. rubens, T. alpestre,* and *T. angustifolium.* This may indicate a difference in the pathogenicity of the rusts employed in the two investigations. On the other hand, it may be due to the use of different strains of the species of clover.

Rust from *Trifolium hybridum*

This rust gave some very interesting results with *Trifolium angustifolium, T. armenium,* and *T. subterraneum.* One strain of *T. angustifolium* was very susceptible to the rust from Ann Arbor; another was very resistant. One strain of each of the other two species was moderately susceptible; other strains were resistant to collections of the rust from Lafayette, Indiana. This indicates that part, at least, of the difference in the results obtained in this study and in Kobel's is probably due to the use of different strains of the species of Trifolium. In this study *Trifolium hybridum* was the only uniformly susceptible species.

Rust from *Trifolium repens*

The results obtained with *Trifolium repens* are very interesting. Three strains of the species gave little or no signs of infection when inoculated. Five strains showed a greater variation. A few uredinia developed on some of the plants. No very susceptible plants were noted. In six strains a majority of the plants were very susceptible. However, a small proportion of the plants in these strains were more or less resistant. In *T. incarnatum* most of the plants were resistant; a few were moderately susceptible. One strain of *T. resupinatum* was very susceptible and two were very resistant. The two strains studied of *T. parviflorum* were moderately susceptible,

and the two of *T. glomeratum* were very susceptible. Therefore, so far as the results of these studies are concerned, *T. glomeratum* and *T. parviflorum* were more susceptible than the species (*T. repens*) from which the rust was obtained.

It is evident that there is a considerable variation in reaction to rust within a number of the species of Trifolium. This will make it difficult to compare results of various investigators unless the same strains of each species are employed. It is, therefore, not possible to make an accurate comparison of the results obtained in these investigations with those of Kobel. He apparently had physiologic forms of the three varieties of rust possessing somewhat greater pathogenicity. His results, however, may have been due in part to more susceptible strains of Trifolium. Kobel has shown that two specialized forms can be distinguished in the variety *fallens* and, to judge from the results which have been obtained with other rusts, it would not be surprising to find differences in pathogenicity within the rusts occurring on red, alsike, and white clover.

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LITERATURE CITED

1. Arthur, J. C. 1934. Manual of the Rusts in United States and Canada. 438 pages. Purdue Research Foundation.
2. Davis, W. H. 1924. Summary of Investigations on Clover Rusts. Mycologia, 16 : 203–219.
3. Kobel, Fritz. 1920. Zur Biologie der Trifolien bewohnenden Uromyces-Arten. Centralbl. Bakt., 52 : 215–235.
4. Liro, J. Ivar. 1906. Kulturversuche mit finnischen Rostpilzen. I. Acta Soc. F. Fl. Fenn., 29 (6) : 1–58.
5. Mains, E. B. 1928. Observations concerning Clover Diseases. Proc. Ind. Acad. Sci., 37 : 355–364.
6. Paul, H. 1917. Vorarbeiten zu einer Rostpilz-(Uredineen-)Flora Bayerns. Kryptogamische Forschungen, 2 : 48–73.

NOTES ON ALPINE AND SUBALPINE DESMIDS FROM WESTERN UNITED STATES

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VERY little attention has been given to the occurrence and distribution of alpine desmids in North America. Such meager information as we have has been contributed, for the most part, in the papers of Borge (1), Wailes (18, 19), Wood (23), Schmidle (15), and Wailes and Tiffany (20).

Much more information is needed before any significant comparisons can be made with the alpine desmid flora in other parts of the world, or generalizations established for distribution in this country. In Europe, and to a certain extent in South America, on the other hand, an enormous amount of work has been done with alpine desmids and much information has been published. The intensive studies of European algologists should serve as a stimulus to students of these plants in North America.

During the summer of 1934 the writer had an opportunity to make a number of collections from alpine and subalpine lakes in the Pacific northwest. In connection with an exploratory survey for forage and soil-retaining plants (for the Bureau of Plant Industry) his investigations took him into several mountain ranges. For the most part, samples were collected from ponds and swamps in the Wallowa Mountains in northeastern Oregon and from the Seven Devils Range, bordering the Snake River in western Idaho. These picturesque and highly eroded ranges rise to altitudes of 9,000–10,000 feet and hold in the flanks of their peaks innumerable small lakes. Collections were made at elevations of 7,000 and 8,000 feet.

The ponds from which the samples were taken did not appear to be, in the main, very promising for the algologist. The bodies of water, for the most part snow-fed, were, of course, very cold. There were no Sphagnum beds about the lakes, which are often associated

with a desmid flora, and the only visible algal growth was a little flocculation on the stems of submerged aquatics. However, several samples proved to be rich in both number and variety of desmids, in addition to many other algae, mostly Myxophyceae.

So far as the writer knows, there are no published reports on the algae of the regions represented by these collections. This preliminary paper will serve, therefore, to increase the list of algae known for Oregon and Idaho, and will also add to our knowledge of alpine desmid distribution. The presence of many lowland forms at 8,000 feet is to be expected, perhaps, but their appearance in alpine collections is significant from the standpoint of distribution. Some forms in these collections are apparently new, and others are interesting because of their having been found but a few times in North America. The writer expects to add to the list given below with supplementary papers that will include some genera of desmids not represented herein.

List of Species

Penium cucurbitinum Biss. f. minus W. and G. S. West; West and West, *British Desmidiaceae*, I : 95, Pl. IX, Fig. 16. 1904.

Length 45 μ; width 21 μ. Pl. XVI, Fig. 8. Seven Devils Range, Idaho. Previously reported from alpine regions in British Columbia.

Cosmarium Boeckii Wille; West and West, *British Desmidiaceae*, III : 234, Pl. LXXXVI, Figs. 26–32. 1908. Forma.

Length 34.5 μ; width 31.5 μ; isthmus 7.5 μ. Seven Devils Range, Idaho. Widely distributed in North America. Much variation is to be noted in this species in the arrangement of granules. Our specimens are more nearly like the form figured by the Wests from North America in *Trans. Linn. Soc. Bot.*, 5, Pl. XV, Fig. 7, than any other American expression.

Cosmarium Botrytis Menegh.; West and West, *British Desmidiaceae*, IV : 1, Pl. XCVI, Figs. 1–2, 5–15. 1911.

Length 109.2 μ; width 89.7 μ; isthmus 26.5 μ. Wallowa Mts., Oregon. Previously reported from alpine regions in Colorado and British Columbia. Generally distributed.

Cosmarium caelatum Ralfs; West and West, *British Desmidiaceae*, III : 134, Pl. LXXVI, Figs. 5–7. 1908.

Length 42 μ; width 33 μ; isthmus 14 μ. Wallowa Mts.,

Oregon. Generally distributed, but no previous alpine record in North America.

Cosmarium Hammeri Reinsch var. homalodermum (Nordst.) W. and G. S. West; West and West, *British Desmidiaceae*, II : 182, Pl. LXII, Figs, 22–23. 1905.

Length 64 μ; width 46.8 μ. Wallowa Mts., Oregon. British Columbia. Newfoundland.

Our specimens showed a peculiar and frequent tendency to form abnormal semicells. In undergoing cell division the semicells do not disengage but build a much enlarged new portion in common, so that there are two isthmi and three semicells. This characteristic has been noted also by Taylor (17).

Cosmarium Hammeri Reinsch var. protuberans W. and G. S. West; West and West, *British Desmidiaceae*, II : 183, Pl. LXII, Figs. 24, 25. 1905.

Length 24 μ; width 21 μ; isthmus 6 μ. Pl. XV, Fig. 18. Seven Devils Range, Idaho. Previously recorded from Michigan and Iowa.

Cosmarium margaritatum (Lund.) Roy & Biss.; West and West, *British Desmidiaceae*, IV : 18, Pl. XCIX, Figs. 8, 10. 1911.

Length 78 μ; width 60 μ; isthmus 21–22 μ. Seven Devils Range, Idaho. Widely distributed.

Cosmarium Meneghinii De Bréb.; West and West, *British Desmidiaceae*, III : 90, Pl. LXXII, Figs. 29–32. 1908. Forma.

Length 24 μ; width 15 μ; isthmus 3.4 μ. Pl. XVI, Fig. 11. Seven Devils Range, Idaho. Widely distributed but no previous alpine record.

Our plants are somewhat larger than usual.

Cosmarium obliquum Nordst.; West and West, *British Desmidiaceae*, III : 49, Pl. LXIX, Figs. 18–21. 1908. *Nothocosmarium obliquum* (Nordst.) Raciborski, *Desm. Nowe*, 1888, p. 98, t. 6, Fig. 13.

Length 21 μ, width 10 μ. Commonly forming short filaments of 4–6 cells. Pl. XVII, Figs. 1–6. Foothills of Cascade Mts., Oregon. Previously reported only from Washington. Our specimens seem to belong to *C. obliquum*, but the preserved material did not show axile chloroplasts, as described for this species, but distinctly parietal. The morphology and the arrangement of cells into filaments, together with the peculiar chloroplast, seem to the

writer to warrant taking this plant from the genus and perhaps assigning it to its original position as a species of Nothocosmarium.

Cosmarium ochthodes Nordst. var. amoebum W. West; West and West, *British Desmidiaceae*, IV : 11, Pl. XCVIII, Figs. 4–6. 1911.

Length 97.5 μ, width 74.2 μ, isthmus 23.4 μ. Pl. XVII, Fig. 7. Wallowa Mts., Oregon. Mississippi, Newfoundland.

Cosmarium ornatum Ralfs, West and West, *British Desmidiaceae*, III : 151, Pl. LXXVIII, Figs. 1–10. 1908.

Length 32 μ, width 35 μ, isthmus 11.7 μ. Seven Devils Range, Idaho. Widely distributed.

Cosmarium ovale Ralfs; West and West, *British Desmidiaceae*, III : 267, Pl. XCII, Fig. 1; Pl. XCIII, Fig. 1; Pl. XCIV, Fig. 1. 1908. Forma.

Length 163.8 μ, width 93.6 μ, isthmus 38 μ. With a double row of granules extending nearly across the base of the semicell, and with a single row within the lateral margins in the lower half of the semicell, two rows within the margins in the lower half and two rows within the margins in the upper half of the semicell. In side view ovate, with a double row of granules at the base of the semicell extending in from the margins but not extending completely across the midregion. With a central band of granules extending from the apex of the semicell to near the base; the band four granules wide at the apex, narrowing to a double row at the base. Pl. XV, Figs. 16–17. Seven Devils Range, Idaho.

This form is remindful of a similar expression described by Prescott and Magnotta (14) from Michigan, but referred to *Cosmarium denticulatum* Borge. A somewhat similar plant has appeared in collections of Isle Royale desmids under the writer's observation. I am of the opinion that the plant referred to above as *C. denticulatum* and the form of *C. ovale* listed above are expressions which have not been hitherto noted or described. The question arises whether or not the typical form of *C. ovale* might possess the granules arranged as mentioned above, a character which has been overlooked because of the great density of the cell content. Certainly this handsome species requires further critical study.

Cosmarium subreinschii W. West var. ocellatum W. and G. S. West; Taylor, *Pap. Mich. Acad. Sci., Arts and Letters*, 19 : 267, Pl. XLVIII, Fig. 8. 1934. Forma.

Length 33 μ, width 32 μ, isthmus 6 μ. With a scrobiculation in the upper part of the semicell and a large papilla at the base, just above the isthmus. Pl. XVI, Fig. 10. Seven Devils Range, Idaho. Typical form reported from Newfoundland. The presence of the papilla at the base of the semicell is a distinct variation and, if constant, our specimens should be given a form name.

Cosmarium subspeciosum Nordst.; West and West, *British Desmidiaceae*, III : 252, Pl. LXXXIX, Fig. 11, 1908.

Length 85.8 μ, width 62 μ, isthmus 25.4 μ. Pl. XVII, Fig. 8. Wallowa Mts., Oregon. No previous alpine record for North America.

Cosmarium taxichondrum Lund.; West and West, *British Desmidiaceae*, IV : 45, Pl. CIII, Figs. 11–13. 1911.

Length 42 μ, width 39 μ, isthmus 9 μ. Seven Devils Range, Idaho. Widely distributed.

Cosmarium tetraophthalmum De Bréb.; West and West, *British Desmidiaceae*, III : 270, Pl. XCV, Figs. 4–7. 1908.

Length 101.5 μ, width 85.5 μ, isthmus 27.3 μ. Wallowa Mts., Oregon. Reported from alpine regions in Colorado. Generally distributed.

Cosmarium tumidum Lund.; West and West, *British Desmidiaceae*, II : 160, Pl. LX, Fig. 18. 1905.

Length 39 μ, width 33 μ, isthmus 9.2 μ. Seven Devils Range, Idaho. Described as rare in Great Britain. Generally distributed in North America.

Xanthidium antilopaeum (De Bréb.) Kuetz.; West and West, *British Desmidiaceae*, IV : 63, Pl. CVIII, Figs. 7–18. 1911. Forma.

Length 46 μ without spines, width 39 μ without spines, isthmus 13.8 μ. Pl. XVI, Fig. 6.

This form is very similar to one figured and described by Borge from Paraguay (*Arkiv f. Bot.*, 1 : CIV, Tab. 4, Fig. 4). It is, however, somewhat smaller than the South American form.

Xanthidium armatum (De Bréb.) Rab. var. fissum Nordst.; West and West, *British Desmidiaceae*, IV : 54, Pl. CV, Figs. 1–2. 1911.

Length 109 μ without processes, 140.5 μ with processes; width 74 μ without processes, 101.5 μ with; isthmus 31.2 μ. Pl. XVI, Fig. 2. Seven Devils Range, Idaho. Previously reported from Newfoundland only.

Xanthidium cristatum De Bréb. var. uncinatum De Bréb.; West and West, *British Desmidiaceae*, IV:73, Pl. III, Figs. 2–4. 1908.

This very common variety showed many modifications in respect to length and disposition of spines. This was especially true of plants from the Cascade Mts. Pl. XVI, Fig. 1. Seven Devils Range, Idaho. Wallowa and Cascade Mts., Oregon.

Xanthidium pseudobengalicum Grönblad; Taylor, *Pap. Mich. Acad. Sci., Arts and Letters*, 19:276, Pl. LVI, Fig. 16. 1934.

Length 70 μ without spines, width 66 μ without spines, 120 μ with spines. Thickness 29 μ. Wall densely punctate. Pl. XVI, Figs. 4–5. Wallowa Mts., Oregon.

This very handsome species has but one other North American record, from Newfoundland. It was orginally described from northern Russia.

Staurastrum aristiferum Ralfs; West and West and Carter, *British Desmidiaceae*, V: 22, Pl. CXXXII, Figs. 10–11. 1924. Forma?

Length 30 μ, width 39 μ with spines, isthmus 6.2 μ. Pl. XV, Figs. 7–8. Seven Devils Range, Idaho.

Our specimens are questionably assigned this name. The spines in ours are directed rather sharply downward, instead of diverging. In shape of semicell and in width of isthmus it is somewhat like var. *protuberans* W. & G. S. West.

Staurastrum Brasiliense Nordst. var. Lundellii W. West; West and West, *British Desmidiaceae*, V:35, Pl. CXXXV, Figs. 12–13. 1924.

Length 160 μ, width 165 μ, isthmus 40 μ. Pl. XV, Figs. 5–6. Seven Devils Range, Idaho. Generally distributed but no previous alpine record.

Staurastrum polonicum Racib., *Krakow Akad. Umiej. Spraw. kom. fizyogr.*, 19:17, Fig. 10. 1884. var. **coronulatum,** var. nov. — Semicellulae coronulatae, basi urceolata; marginibus lateralibus in lobum brevem horizontalem rotundatum productis; 2–3 lobis similibus in semicellulae facie visis; apice in 4 lobos (quorum duo videntur) sursum directos diviso, margine inter lobos concava; sinu extrinsecus late aperto, in apicem acutum gradatim contracto; isthmo latissimo; cellulae membrana crasse granulata, granulis in annulis concentricis circum lobos dispositis; a vertice visae orbiculatae, 8 lobis brevibus radiantibus lateque

rotundatis ornatae, incisuris apice obtuso, spatio quo lobi separantur lobi latitudini fere aequali; circulo 4 loborum ad medium spatium intermarginale posito; lobis granulos in 5 seriebus dispositos praebentibus; latitudine 40–43 μ; longitudine 50–53 μ; crassitudine 40–43 μ; isthmo 14.5–16 μ. Pl. XV, Figs. 11–15. Wallowa Mts., Oregon.

This variety differs from the typical chiefly in the shape and the number of apical lobules. In face view the incisions between the lobules are much deeper and more pronounced. In vertical view there are 4 of these lobules rather than 6, as in the typical form. The size of our plants is approximately that of the typical, but the proportions are different, the Idaho plants being slightly longer in relation to width. This is the first record for *St. polonicum* on the continent. (See the note on page 145.)

STAURASTRUM CUSPIDATUM De Bréb. (forma).

Width 37 μ with spines, 19.5 μ without spines. Pl. XVII, Fig. 9. Wallowa Mts., Oregon.

Our specimens appear to be identical with a form which is illustrated by Delponte, *Specimen Desmidiacearum subalpinum*, Pl. 10, Fig. 31. 1873.

STAURASTRUM LONGISPINUM (Bail.) Arch.; West and West and Carter, *British Desmidiaceae*, V : 33, Pl. CXXXIV, Fig. 1. 1924.

Length 97.5 μ, width 136.5 μ (with spines). Pl. XV, Figs. 1–2. Seven Devils Range, Idaho. Previously reported from North America in Florida only.

STAURASTRUM LONGISPINUM (Bail.) Arch. var. BIDENTATUM (Wittr.) W. and G. S. West; West and West, *British Desmidiaceae*, V : 34, Pl. CXXXIV, Figs. 2–3. 1924.

Length 81.9 μ, width 89.7 μ without spines, isthmus 23 μ. Pl. XV, Figs. 3–4. Seven Devils Range, Idaho. Previously reported from New York, New Hampshire, and Newfoundland.

STAURASTRUM MINNESOTENSE Wolle; Smith, *Phytoplankton of the Inland Lakes of Wisconsin. II*, Wis. Geol. and Nat. Hist. Surv., Bull. 57 : 81, Pl. 71, Figs. 14–15. 1924.

Length 105.3 μ with spines, 91.5 μ without spines; width with spines 124.8 μ, without spines 81.9 μ. Pl. XV, Figs. 9–10. Seven Devils Range, Idaho.

Our specimens frequently showed an additional number of spines at the angles.

STAURASTRUM PACHYRHYNCHUM Nordst.; West and West, *British Desmidiaceae*, IV : 151, Pl. CXXI, Figs. 8–9. 1911.

Length 36 μ, width 35 μ, isthmus 7.8 μ, Pl. XVII, Fig. 12. Seven Devils Range, Idaho. Previously reported from Minnesota, Michigan, and Pennsylvania.

EUASTRUM BIDENTATUM Naeg.; West and West, *British Desmidiaceae*, II : 39, Pl. XXXVII, Figs. 16–19. 1905.

Length 60.4 μ, width 37 μ, isthmus 10 μ. Pl. XVII, Fig. 13. Wallowa Mts., Oregon. Previously reported from alpine Colorado. Generally distributed.

EUASTRUM DIDELTA (Turp.) Ralfs: West and West, *British Desmidiaceae*, II : 15, Pl. XXXV, Figs. 3–7. 1905.

Length 140 μ, width 66.3 μ, thickness 46.8 μ, isthmus 12 μ. Pl. XVII, Fig. 10. Seven Devils Range, Idaho. Widely distributed.

EUASTRUM GEMMATUM De Bréb.; West and West, *British Desmidiaceae*, II : 63, Pl. XXXIX, Fig. 19. 1905.

Length 54 μ, width 69 μ, isthmus 9.4 μ. Pl. XVI, Fig. 9. Seven Devils Range, Idaho. Generally distributed.

EUASTRUM OBLONGUM (Grev.) Ralfs; West and West, *British Desmidiaceae*, II : 12, Pl. XXXIV, Figs. 7–9; Pl. XXXV, Fig. 2. 1905.

Length 148 μ, width 70 μ, isthmus 19.5 μ. Pl. XVI, Fig. 7. Seven Devils Range, Idaho. Widely distributed.

EUASTRUM PINNATUM Ralfs; West and West, *British Desmidiaceae*, II : 10, Pl. XXXIV, Figs. 3–6. 1905. Forma.

Length 117 μ, width 78 μ, isthmus 19.5 μ. Pl. XVI, Figs. 3, 12. Seven Devils Range, Idaho.

Our specimens are assigned to *Euastrum pinnatum*, but they show some noteworthy variations from this species which suggest hybridization. The upper lateral angles and the polar lobe are clearly those of *pinnatum*, as is the disposition of protuberances in face view. The proportionately greater width and the basal angles suggest *E. humerosum* Ralfs. The mucilage pore between the two central protuberances is a character of *E. oblongum* (Grev.) Ralfs. The open sinus (not narrowly linear in any specimens observed) is a character that belongs to none of the species mentioned above, as they are described. It occurs to the writer that the mucilage pore may be a character of *E. pin-*

natum which has been overlooked in describing and figuring this plant. In Plate XVI, Figure 12, is shown an apparent encystment of *E. pinnatum*. A very thick membrane has been formed about the cell, apparently by the contracting and solidification of the surrounding mucilage. This membranous covering suggests an explanation for the ability of desmids to become dormant over a period of unfavorable environmental conditions without resorting to zygospore formation.

Euastrum sinuosum Lenorm. var. reductum W. and G. S. West; West and West, *British Desmidiaceae*, II : 22, Pl. XXXVI, Figs. 2–3. 1905.

Length 60.5 μ, width 39 μ, isthmus 12 μ. Pl. XVII, Fig. 11. Seven Devils Range, Idaho.

Euastrum spinulosum Delp. var. inermius Nordst.; Krieger, *Archiv f. Hydrobiol.*, Suppl. 11 : 215, Pl. 21, Fig. 7. 1932.

Length 81.9 μ, width 66.3 μ, isthmus 19.5 μ. Pl. XVII, Figs. 16–17. Wallowa Mts., Oregon. New for North America. The typical form has been reported from Indiana.

Our specimens are a little larger than usually given for this variety.

Euastrum verrucosum Ehr. var. alatum Wolle; West and West, *British Desmidiaceae*, II : 67, Pl. XL, Fig. 6. 1905.

Length 105.3 μ, width 89.7 μ, isthmus 23.4 μ. Pl. XVII, Fig. 15. Seven Devils Range, Idaho. Generally distributed.

Euastrum verrucosum Ehr. var. rhomboideum Lund.; *Nov. Acta Reg. Soc. Ups.*, 8 (3), Pl. XV, Figs. 8a, 8b. 1871; Borge, *Arkiv f. Bot.*, 18, No. 10 : 16, Taf. 2, Fig. 17. 1922. Forma.

Length 113 μ, width 113 μ, isthmus 32 μ. Pl. XVII, Fig. 14. Seven Devils Range, Idaho.

This variety, as figured by Lundell (11), does not show the prominent lateral extensions just below the apical lobe. Homfeld (7) and Borge (2) have figured expressions of this plant similar to ours and they assign it to var. *rhomboideum*. Cushman (5) and Wailes (19) have forms which they designate as unnamed varieties. It is the opinion of the writer that this form should be separated from the variety as originally described by Lundell.

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BIBLIOGRAPHY

1. Borge, O. 1909. Nordamerikanische Süsswasseralgen. Arkiv f. Bot., 8 (13) : 1–29, 1 pl.

2. —— 1922. Beiträge zur Algenflora von Schweden. *Ibid.*, 18 (10) : 1–35, Taf. 1–2.

3. Brown, Helen J. 1930. The Desmids of the Southeastern Coastal Plain Region of United States. Trans. Am. Microsc. Soc., 49 : 97–139, pls. XI–XIV.

4. Cushman, J. A. 1904. Desmids from Newfoundland. Bull. Torr. Bot. Club, 31 : 581–584, pl. 26.

5. —— 1904. Desmids from Southwestern Colorado. *Ibid.*, pp. 161–164, pl. 7.

6. —— 1906. Some Desmids from Newfoundland. *Ibid.*, 33 : 607–615.

7. Homfeld, H. 1929. Beiträge zur Kenntnis der Desmidiaceen Nordwestdeutschlands, besondere ihrer Zygoten. Pflanzenforschung, 12 : 1–97, 1 map, 9 pls.

8. Hylander, C. J. 1928. The Algae of Connecticut. State of Conn. Geol. and Nat. Hist. Survey, Bull. 42. Hartford, Conn.

9. Krieger, W. 1932. Die Desmidiaceen der deutschen limnologischen Sunda-Expedition. Arch. f. Hydrobiol., Suppl. 11 : 129–230. Taf. III–XXVI.

10. Lagerheim, G. 1885. Bidrag till Amerikas Desmidié-flora. Öfvers. af Kongl. Vetensk.-Akad. Förhandl., 42 (7) : 225–255. Taf. 27.

11. Lundell, P. M. 1871. De Desmidiaceis quae in Suaecia inventae sunt observationes criticae. Nova Acta reg. soc. scient. Upsala 8, Ser. 3, 100 pages, 5 pls.

12. Moore, Caroline S., and Moore, Laura B. 1930. Some Desmids of the San Juan Islands. Publ. Puget Sound. Biol. Station, 7 : 289–336.

13. Prescott, G. W. 1935. Notes on the Desmid Flora of New England. II. Rhodora, 37 : 113–121, pls. 329, 330.

14. —— and Magnotta, Angelina. 1935. Notes on Michigan Desmids, with Descriptions of Some Species and Varieties New to Science. Pap. Mich. Acad. Sci., Arts and Letters, 20 (1934) : 157–170.

15. Schmidle, W. 1895. Einiger Algen aus Denver, Colorado, U.S.A. Hedwigia, 34 : 84–85, 3 text figs.

16. Smith, G. M. 1924. Phytoplankton of the Inland Lakes of Wisconsin. II. Desmidiaceae. Wis. Geol. and Nat. Hist. Surv., Bull. 57, Part II. Madison, Wisconsin.

17. Taylor, Wm. Randolph. 1934. The Fresh-Water Algae of Newfoundland. Pap. Mich. Acad. Sci., Arts and Letters, 19 (1933) : 217–278, pls. 45–57.

18. Wailes, G. H. 1933. Freshwater Algae and Protozoa from Alaska. Art, Historical and Scientific Association Bull., Vancouver City Museum. March, 1933.

19. Wailes, G, H. 1933. Protozoa and Algae from Mount Hopeless, B.C. Art, Historical and Scientific Association Bull., Vancouver City Museum. November, 1933.

20. —— and Tiffany, L. H. 1929. Some Algae from British Columbia. Museum and Art Notes (Vancouver), 4: 4–10.

21. West, W., and West, G. S. 1904–12. A Monograph of the British Desmidiaceae, Vols. I–IV. Ray Society, London.

22. —— —— and Carter, Nellie. 1924. *Ibid.*, Vol. V. Ray Society, London.

23. Wood, H. C. 1869. Desmids from the White Mountains. Proc. Acad. Nat. Sci. Phila., pp. 15–19.

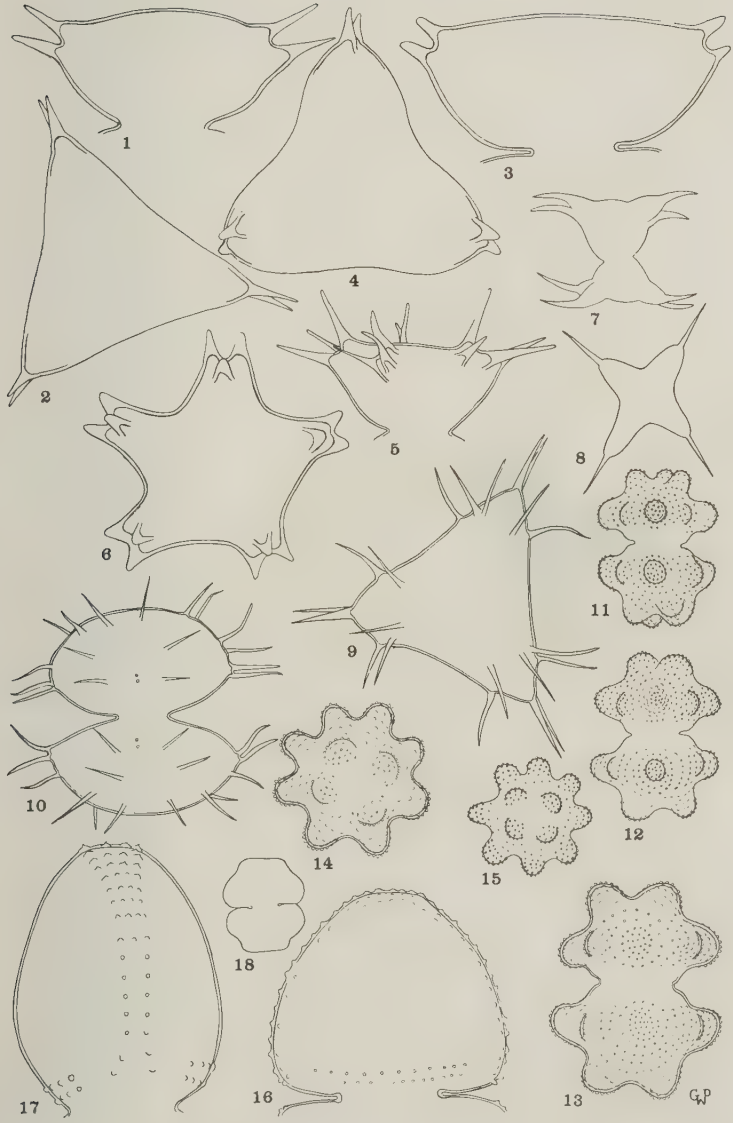
NOTE

Since the writing of this paper Dr. Nellie Carter has published "Alpine Desmids from British Columbia," *Linn. Soc. Journ. Bot.*, 50: 151–174. 1935. Included is a plant (p. 172, figs. 29-30) identical with *Staurastrum polonicum* var. *coronulatum*, var. nov. (pp. 140–141 of my article), a form which she has named *Euastridium verrucosum*, sp. n. My preference for retaining this plant in the genus Staurastrum will be discussed in a later paper.

EXPLANATION OF PLATE XV

1–2. Staurastrum longispinum, × 264
3–4. St. longispinum var. bidentatum, × 352
5–6. St. Brasiliense var. Lundellii, × 264
7–8. St. aristiferum, × 480
9–10. St. minnesotense, × 264
11–15. St. polonicum var. coronulatum, var. nov.; 11–13, × 352; 14–15, × 480
16–17. Cosmarium ovale forma; 16, × 264; 17, × 352
18. C. Hammeri var. protuberans, × 352

PLATE XV



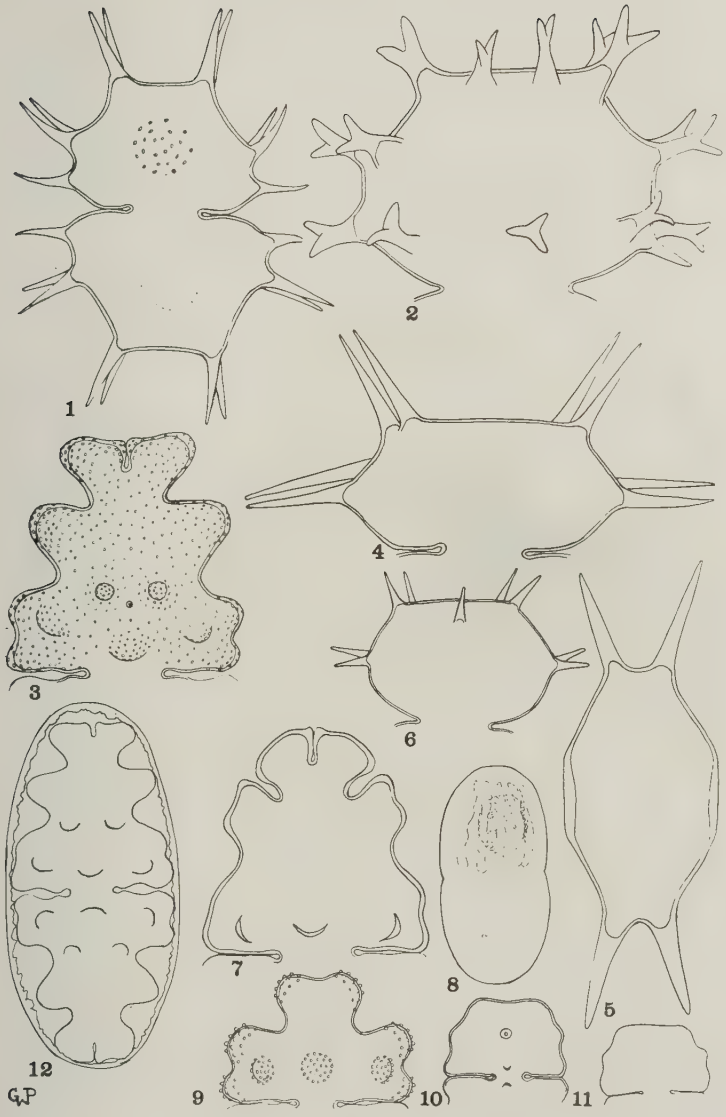
EXPLANATION OF PLATE XVI

1. Xanthidium cristatum var. uncinatum, × 440
2. X. armatum var. fissum, × 440
3. Euastrum pinnatum forma, × 440

4–5. Xanthidium pseudobengalicum, × 440

6. X. antilopaeum forma, × 600
7. Euastrum oblongum, × 330
8. Penium cucurbitinum forma minor, × 600
9. Euastrum gemmatum, × 600
10. Cosmarium subreinschii var. ocellatum, × 600
11. C. Meneghinii, × 600
12. Euastrum pinnatum forma, × 330

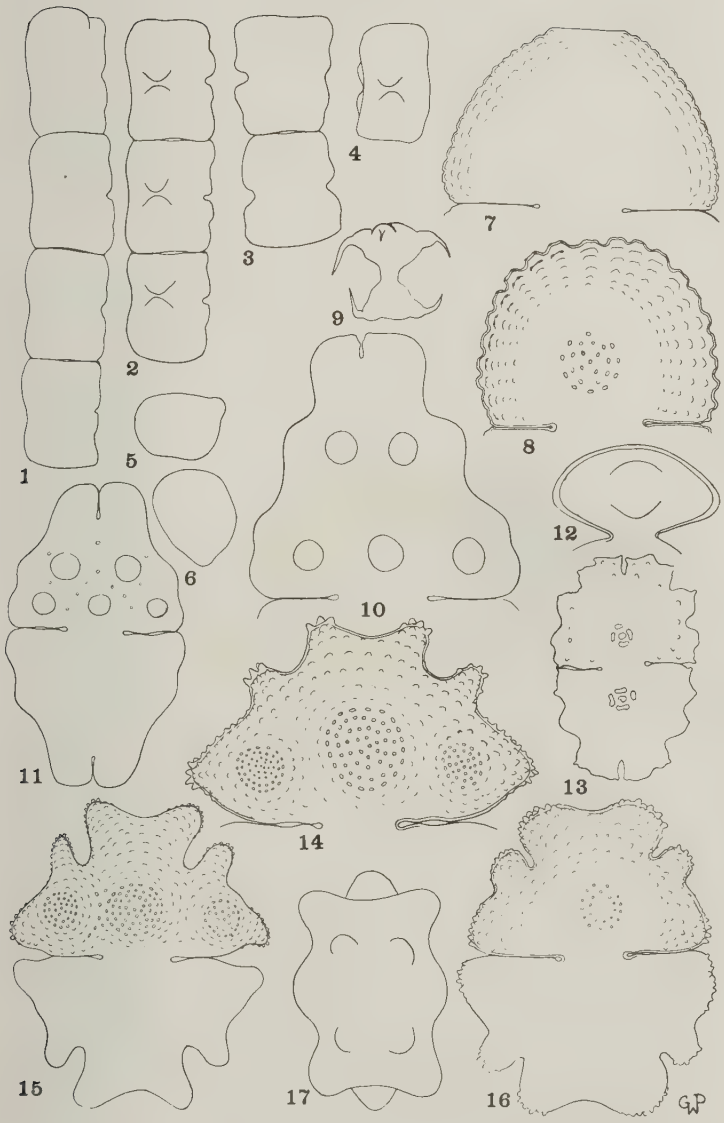
PLATE XVI



EXPLANATION OF PLATE XVII

1–6. Cosmarium obliquum, × 600
7. C. ochthodes var. amoebum, × 440
8. C. subspeciosum, × 440
9. Staurastrum cuspidatum forma, × 440
10. Euastrum Didelta, × 440
11. E. sinuosum var. reductum, × 440
12. Staurastrum pachyrhynchum, × 600
13. Euastrum bidentatum, × 440
14. E. verrucosum var. rhomboideum, × 330
15. E. verrucosum var. alatum, × 330
16 17. E. spinulosum var. inermius, × 440

PLATE XVII



UNUSUAL AGARICS FROM MICHIGAN. III *

ALEXANDER H. SMITH

IN THE following account a total of twenty-four species distributed in thirteen genera of the Agaricaceae are discussed. Sixteen of these have apparently not been previously reported as occurring within the State of Michigan. *Galerula siliginea* (Fr.), comb. nov., and *Collybia palustris* (Pk.), comb. nov., have been proposed.

The collections from Wilderness State Park in Emmet County, and also those from the vicinity of the University of Michigan Biological Station at Douglas Lake, Cheboygan County, were of exceptional interest, and indicate that continued collecting in these areas during the fall months will yield much additional information concerning the agaric flora of the state.

The changes in the fungous flora of a recently burned-over bog (Mud Lake Bog) near Whitmore Lake, Washtenaw County, are also being followed with considerable interest. Before being burned the bog was visited frequently by the mycologists of Ann Arbor, and thus its fungous flora was comparatively well known. Since the fire in 1931 the writer has visited the area regularly, and many agarics not previously found there have been recorded. In fact, many of the species are apparently first reports for the state and have furnished very interesting data on the distribution of species in this family.

The collection numbers and the photographs are those of the writer unless otherwise stated. The collections have been deposited in the Herbarium of the University of Michigan.

List of Species

COLLYBIA AMBUSTA Fr. (Pl. XXI, Fig. 3). — Pileus 1–3.5 cm. broad, convex at first, with a slight umbo, in age expanded-

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 534.

plane, slightly depressed or with a small almost papillate umbo, glabrous, when moist lubricous to subviscid, subhygrophanous, entirely opaque or striatulate on the paler margin, "bone-brown"[1] to "fuscous," margin slightly paler, fading to "wood brown" or "bister" (at first a blackish cast is predominant but in age sordid brown colors are prominent), margin incurved when young; flesh dark gray, cartilaginous; lamellae narrow, close, adnate, tapering to the margin, pale grayish at first, becoming grayish brown (nearly "avellaneous"), darker in age; stipe 3–4 cm. × 1–3 mm., concolorous with pileus or paler, terete or compressed, tough, glabrous to coarsely pruinose-scabrous at the apex, flesh blackish, base gray and cottony from the matted mycelium; spores 4–5.5 μ, globose, smooth, basidia four-spored, 38–42 × 6–7 μ; cystidia not differentiated; pileus trama filamentose, surface covered by a very thin subgelatinous pellicle; odor and taste farinaceous.

Collections 33–1010 and 33–1145 were made on the burned area of Mud Lake Bog, Whitmore Lake, Sept. 25 and Nov. 3, 1933, respectively. The close narrow gills and the pruinose stipe separate the species from *C. atrata* Fr. The spores appear to be roughened owing to the presence of many small oil droplets near the periphery, but the exospore is smooth. Some spores appeared to be obscurely angled. A form was found in shaded mossy places (33–1146, Nov. 3, 1933) in which the stems measured 4–7 cm. × 1–2 mm. It was typical in other respects however.

Collybia palustris (Peck), comb. nov. (= *Agaricus paluster* Peck, *Ann. Rep. New York State Cab.*, 23 : 82. 1872; *Mycena palustris* (Pk.) Sacc., *Syll. Fung.*, 5 : 282. 1887; *Agaricus leucomyosotis* Cooke and Smith, *Grevillea*, 13 : 57. 1885; *Collybia leucomyosotis* (Cke. & Smith) Sacc., *Syll. Fung.*, 5 : 220. 1887). — Pileus 1–2.5 cm. broad, convex with a small papilla, broadly conic and papillate, plane or slightly umbilicate, often becoming broadly campanulate with a sharp umbo, "olive-brown" when fresh, pellucidly striate to near the apex, fading to grayish white near the margin or "buffy brown," very hygrophanous, covered by a white bloom when young, glabrous, margin inrolled

[1] All names of colors within quotation marks are taken from R. Ridgway, *Color Standards and Color Nomenclature*, 1912.

and white-pruinose; flesh soft and watery; odor and taste farinaceous; lamellae narrow to broad, close to subdistant, adnate or with a slight tooth, "pale smoke gray," becoming watery gray, rather thick at times and somewhat venose, the faded cap and gills nearly unicolorous; stipe 4–10 cm. × 2–7 mm. dia., gray, paler than the pileus, covered by a white pruinosity when young, glabrous in age, hollow, very watery and fragile; spores 6–8 × 4–5 μ; basidia four-spored, 25–28 × 6–8 μ; cystidia not differentiated; pileus trama homogeneous.

This is a common fungus in sphagnum bogs during the spring and early summer. Coker and Beardslee (3) have followed Lange and Schroeter in using the name *C. clusilis* Fr. for this species, and have also pointed out that *Mycena paluster* Pk. is the same. Specimens and photographs of the Michigan collections were sent to Mr. A. A. Pearson in England, who has reported that the plant is well known there under the name *Collybia leucomyosotis* Cooke & Smith. In his letter Mr. Pearson stated that cystidia were not present in the English material. A very different Collybia is also known under the name *C. clusilis* in Europe, apparently much more commonly known than the fungus Schroeter collected. Thus it seems best to use the name *C. clusilis* for the former fungus. Since the description of *Agaricus* (*Collybia*) *leucomyosotis* was published in 1885 and that of *Agaricus* (*Mycena*) *paluster* in 1872, it becomes necessary to use the older specific name in a new combination. The specimens illustrated in Plate XVIII were collected on sphagnum in Mud Lake Bog, Washtenaw County, May 21, 1932 (32–8).

Cortinarius mucosus (Bull.) Ricken *sensu* Kauffman (8). — Under pine at Wilderness State Park, Emmet Co., Oct. 12, 1934 (1142). Kauffman (8) gives the distribution of this species as from Maryland to Alabama.

Cortinarius sphagnophilus Peck. — Singly in a sphagnum bog, Cheboygan Co., Oct. 8, 1934 (1102). Kauffman (8) states that this species is known only from the type locality. The writer's material is typical in every respect. The watery spots were conspicuous and confined to a zone near the margin of the cap. The stems measured 12–15 cm. × 12–13 mm. and were faintly violaceous at first.

Dictyolus retirugis (Fr.) Quél. (Pl. XXV, Fig. 4). — On *Trichocholea tomentella* (Ehrh.) Dum. in Rees' Bog, Burt Lake, Cheboygan Co., Oct. 18, 1934 (1161). Pileus 5–10 mm. broad, membranous, broadly spatulate, grayish brown, very pale but striae dark and conspicuous, surface unpolished, margin incurved and minutely tomentose; lamellae radiating, very narrow and foldlike, strongly intervenose and at times appearing almost subporoid; stipe lacking, point of attachment eccentric or lateral; spores 8–10 × 6–8 μ.

This species seems to be both rare and widely distributed. Kauffman (7) reported it from Mt. Hood, but described the spores as 7–8 × 4–4.5 μ. Bresadola (2) describes the spores of *Cantharellus bryophilus* Pers. as 6–8 × 3.5–4.5 μ and those of *C. retirugis* Bull. as 8–10 × 5.5–7 μ. The spores of the Michigan material agree well with the measurements of Bresadola.

Galerula capillaripes (Pk.) Murr. (Pl. XXI, Fig. 2). — Pileus 3–15 mm. broad, convex to obtusely conic, subhygrophanous, near "olive-brown" or "mummy-brown" at first, rather dry and with a hoary sheen, fading to near "avellaneous" and then atomate, margin slightly striate; lamellae close, equal, moderately broad, narrowly adnate, edge even, pallid, becoming dull ochraceous tawny; stipe 1.5–3 cm. × 1–2 mm., pale gray and striate at first or white fibrous-pruinose, sometimes glabrous in age, base dark brown or becoming vinaceous brown; odor and taste none; consistency very fragile; spores 9–11 × 6–7 μ, pale ochraceous; cystidia on gill edge only, 8–10 μ broad, "ninepin"-shaped; pileus corticated by a layer of inflated pyriform cells, occasional narrow hyphae project through the layer and cause the hoary appearance of the young pilei.

The fruiting bodies are extremely fragile and difficult to handle. So far as the writer has been able to determine, the species has never been adequately illustrated. His collections were made on freshly manured soil on the campus of the University at Ann Arbor, July 5, 1934 (52).

Galerula siliginea (Fr.), comb. nov. (Pl. XXI, Fig. 1). (= *Galera siliginea* Fr., *Epicrisis Systematis Mycologici*, p. 205. 1836). — Pileus 8–25 mm. broad, obtusely conic, becoming obtusely campanulate in age, often splitting to the disk, rarely somewhat expanded, glabrous, viscid at first, subviscid to lubricous at

maturity, "light grayish olive" to "smoke-gray" or darker and a dull steel-gray at first, becoming more brownish in age, umbo usually "buffy brown," "cinnamon-buff," or "cream-buff," with a grayish cast always present, not striate, subhygrophanous; lamellae close, narrow to moderately broad in age, equal, whitish gray then ochraceous tawny, edge white; stipe 3–7 cm. × 1–2 mm., equal, pallid gray, longitudinally fibrous-striate over all when young, white pruinose-fibrous in age or becoming nearly glabrous, striae sometimes disappearing; odor and taste none; consistency rather firm; spores 12–16 × 7–9 μ, ellipsoid, pale ochraceous under the microscope; basidia two-spored, 28–30 × 8–11 μ; cystidia on gill edge only, 25–28 × 7–9 μ, "ninepin"-shaped; pileus trama corticated by an even row of pyriform pedicellate cells, a thin layer of gluten covers this layer in the unexpanded pilei.

This species was exceptionally abundant on a new seeding of grass on the University Campus at Ann Arbor, June 12, 25, and 26, 1934 (14, 43, 48). The gray colors were characteristic, the buttons and the unexpanded pilei being practically pale fuligineous similar to many species of Mycena. The brownish colors come into prominence at maturity.

Gomphidius glutinosus Fr. (Pl. XIX). — Gregarious under red pine, Oct. 10, 1934, Wilderness State Park, Emmet Co. (1122). When young the pilei were "dark vinaceous gray" to "vinaceous slate" and "cinnamon-drab" when fading. In age they were "brownish drab" or brighter. The stems were intensely yellow at the base and white above. The veil was gelatinous and very well developed, which caused the cap and stipe to be very glutinous, and the gills were white at first. Murrill (13) gives the distribution as "northeastern United States." Kauffman collected it in Idaho. This, with the writer's collection, indicates a much wider distribution.

Gomphidius viscidus f. columbiana Kauff. (Pl. XX). — Under *Pinus resinosa* Ait., University of Michigan Biological Station, Douglas Lake, Cheboygan Co., Oct. 10, 1934 (1105, 1121). Two forms were found, one with the cuticle broken up into large patches and the second glabrous and typical. Collections were made during a dry spell following a period of heavy rainfall, and it is quite likely that the breaking of the cuticle into patches

was due to weather conditions. The stems were covered by "orange-rufous" fibrils up to the obsolete annular zone. When handled, the flesh of the stem and the fibrils became a delicate rose color, which deepened into a dull red as the specimens dried. Kauffman (6) says: "This American form occurs definitely throughout the Rocky Mountain and Pacific Coast states. Specimens from California slightly larger than usual are in the herbaria mentioned. Whether any of the collections from eastern United States usually referred to *G. viscidus* actually belong there I am unable to say." The report of the foregoing form by Bisby, Buller, and Dearness (1, p. 120), from Kenora, and the Michigan collections extend its range eastward to the Great Lakes region. The pilei in collection 1105 measured up to 7 cm. broad, but were identical in other respects.

Hygrophorus chrysodon Fries. — On needle beds under conifers, Oct. 11, 1934, Rees' Bog, Cheboygan Co. (1138). Kauffman included this species in his *Agaricaceae of Michigan*, but stated that it had not been found in the state. The writer's collection was typical in every respect.

Hygrophorus tephroleucus Fr. — Pileus 10–25 mm. broad, convex to plane, occasionally slightly depressed, viscid, appearing appressed-fibrillose under a lens at first, in age fibrils arranged in small patches, but the surface appearing nearly glabrous to the naked eye, pale gray, disk sometimes darker, becoming ashy to whitish gray in age; lamellae subdistant, adnate-decurrent, broad, white; stipe, white fibrous-punctate near the apex, more or less fibrillose below, solid, in age the fibrous points tend to become gray or blackish, viscid when young, dry at maturity, the gelatinous sheath very delicate and often young specimens appear to be without it; spores 8–10 × 4–5 μ, ellipsoid; no cystidia seen; pileus with a thin gelatinizing pellicle, otherwise homogeneous; gill trama of divergent hyphae.

Abundant on débris and needles, Mud Lake Bog, Cheboygan Co., Oct. 8, 1934 (999); Rees' Bog, Cheboygan Co., Oct. 9, 1934 (1108), and Oct. 11 (1135). As a rule, the margin of the pileus is even, but in some specimens it was sulcate to broadly "scalloped." The white fibrils on the stipe, which darken in age, are characteristic.

Lactarius resimus Fr. — Under aspen and balsam, Wilderness

State Park, Emmet Co., Oct. 12, 1934 (1232), and at Cross Village, Oct. 7 (994). The fruiting bodies were pure white, and the pilei were viscid. The coarse, matted tomentum near the margin was very characteristic, and the large spots on the stipe distinguish it from *L. cilicioides* Fr., which in addition is said to have scanty milk and somewhat darker colors.

Naucoria centuncula Fr. (Pl. XXIV, Fig. 2). — Pileus 6–40 mm. broad, convex to flat when young, plane or with a turned-up margin at maturity, glabrous, hygrophanous (obscurely so in large specimens), striate, striae usually conspicuous, "sepia," "Saccardo's umber," or "Isabella color," when faded the disk often becomes lighter than the margin; lamellae close, adnexed, narrow to moderately broad, concolorous with the pileus, edge white-fimbriate; stipe 1–2 cm. × 1.5–3 mm., watery, concolorous with the pileus, evenly covered by minute paler fibrils, tubular, base more or less cottony; odor when flesh is crushed, acidulous; taste sharp; spores 6–6.5 × 4 μ, 6–7 × 4 μ, 7–8 × 4–4.5 μ, broadly oval or flattened on one side, basidia four-spored, 30–33 × 6–7 μ; cystidia on gill edge only, fusoid-ventricose to clavate, 30–40 × 7–11 μ; pileus trama homogeneous, of elongated cells 6–10 μ in diameter, those near the surface colored.

On decaying wood of deciduous trees, rather common in both the northern and southern portions of the state (Ann Arbor, Sept. 23, 1933 [33–1004]; Harbor Springs, Aug. 17 [33–645]; Cross Village, Aug. 21 [33–727]; Trout Lake, Aug. 24 [33–738]). The photograph was taken by Professor E. B. Mains. This very ordinary-appearing fungus is not rare, but one seldom collects the small nondescript fruiting bodies in sufficient numbers to warrant a careful study. The plants described above are considered typical by the writer. We have in the state several forms approaching this species very closely which still remain to be studied. Kauffman reported this species, but had not studied it critically.

Naucoria firma Peck. — Collected by C. H. Kauffman at New Richmond, Sept. 12, 1920. This collection was found among Professor Kauffman's undetermined specimens. For a description and an illustration of this species see Smith and Wehmeyer (14).

Naucoria lubriciceps Kauff. & Smith (Pl. XXV, Fig. 2). — This species was exceptionally abundant in Rees' Bog and at Mud Lake Bog in Cheboygan Co., during October, 1934 (Oct. 8 [997]; Oct. 9 [1111]; Oct. 11 [1140]; Oct. 17 [1230]). The spores of these collections were found to measure (7) 8–10 × 5–6 μ. In the original description (9) they were given as 5.5–7 × 3–4 μ. Upon reëxamining the type specimens the spores were found to measure 6–8 × 4–5 μ or 7–9 × 4–5.5μ (in different pilei). The measurements of the spores of the 1934 collections were all made from spore deposits. The pileus trama has a compact layer of tissue over the surface which appears to be cellular in tangential section. The size of the cells varies considerably, but in the writer's collections they measured 5–10 (12) μ in diameter. In the younger pilei, because of the compact nature of the remainder of the flesh, the trama appears practically homogeneous. In age the surface layer gelatinizes slightly and causes the cap to feel slippery when touched. Frosted pilei are frequently subviscid.

Omphalia bisphaerigera Lange. — Gregarious on sphagnum or other mosses in bogs and under spruce in more open woods. Pileus 5–20 mm. broad, conic to convex, often without an umbo or with a slightly depressed disk, fuligineous to watery gray, hygrophanous, fading to a sordid pallid gray, sometimes nearly white, glabrous, striate when moist, opaque when faded, cartilaginous (small water-soaked specimens flaccid), margin curved in against the gills but not inrolled; odor and taste farinaceous; lamellae close to subdistant, bluntly adnate or with a decurrent tooth, in age subdecurrent, narrow to moderately broad, widest at base, concolorous with pileus; stipe 3–7 cm. × 1–2.5 mm., fragile-cartilaginous, rigid (subflaccid if in a very wet habitat), pale gray to nearly white, glabrous, subtranslucent, undulate, and often crooked; pileus trama evenly filamentose; spores 7 9 (10) μ, globose, appearing finely echinulate, pale bluish gray with chloralhydrate-iodine; basidia two-spored; cystidia not differentiated or 25–30 × 7–9 μ and subfusoid.

This species was fairly abundant in Rees' Bog, Burt Lake, Cheboygan Co., during Oct., 1934 (1088, 1106, 1133, 1148, 1164). Kühner (11) has described this species accurately, but since his description is rather inaccessible to American investigators it

seemed best to describe the American collections. As he has pointed out, the species is quite variable. Some collections have the aspect of a Mycena, some of a Collybia, and some of an Omphalia. In fact, the specimens which the writer collected reminded one more of a Mycena than of an Omphalia. The gills were nearly always bluntly adnate. The spores, however, are its most distinctive character and "possède une membrane triple composée d'une épispore lisse et amyloïde et deux autres membranes non amyloïdes: une mésospore ornée et un endospore lisse bien distincte" (Kühner, p. 68). Lange (12) has given the name *Omphalia bisphaerigera* to the plant Ricken described as *O. striaepilea* Fr.

Omphalia detrusa Fr. (Pl. XXII, Fig. 1). — Pileus 2–5 cm. broad, center depressed, margin inrolled, convex to somewhat flattened, becoming nearly plane with a depressed disk or subinfundibuliform at maturity, the margin remaining broadly decurved or approximately horizontal, densely pruinose at first, evenly "bister" over all, glabrous, margin faintly striatulate or opaque when moist, hygrophanous, fading to a dull ash gray; flesh soft and watery "bister" when moist, pallid when faded; lamellae close, narrow to moderately broad, broadly adnate to subdecurrent at first, decurrent at maturity, "buffy brown" usually with a glaucous sheen; stipe 3–5 cm. × 2–4 mm., color of the pileus, glabrous above the white cottony base, longitudinally striate from the splitting of the cuticle; spores 4–5 × 3–4 μ (not including projections), covered with projections 1.5–2 μ long; cystidia not differentiated.

Gregarious on sphagnum, Oct. 13 and 16, 1934, Mud Lake Bog, Cheboygan Co. (1149, 1159). This is a very distinct species and is most closely allied to the large form of *Omphalia epichysium*, which is found on humus and moss. The spores definitely separate the two, however. The stems in the collections given above were found to be attached deep in the moss. The pilei seldom projected more than one or two centimeters above the sphagnum, and as a rule they were either partially buried or resting directly on it. The stems are very weak, but do have a cartilaginous rind. This, together with the relationship to *O. epichysium*, clearly places the fungus in Omphalia.

Omphalia epichysium Fr. (Pl. XXII, Fig. 2; Pl. XXIII, Figs. 1–3).

There are three forms of this species in Michigan which can be distinguished by their habitat. The form described by Kauffman in *Agaricaceae of Michigan*, p. 818, is the typical form. It is common throughout the state on decaying logs. The photograph (Pl. XXIII, Fig. 1) was taken by Professor E. B. Mains from material collected near Harbor Springs.

The second form is illustrated by Figure 2, Plate XXII, and Figure 2, Plate XXIII. This form is usually found growing singly to gregariously on humus among mosses such as *Polytrichum juniperinum* Wild., but it has been found on charred humus and among sphagnum as well. The description is of the collection from which the photographs were made. Pileus 1.5–4.5 cm. broad, flat or slightly umbilicate when young, becoming broadly vase-shaped in age, but the margin remaining decurved or becoming horizontal, glabrous, hygrophanous, "mummy-brown" or nearly black, becoming grayish brown when faded, margin more or less striate when moist; flesh soft and watery; lamellae long-decurrent, distant to subdistant, narrow (3 mm.), grayish brown with a glaucous bloom, darker in age, slightly intervenose; stipe 3–4 cm. × 2–5 mm., terete or compressed, dark "mummy-brown" to blackish, grayish cottony or tomentose below, glabrous and smooth above, watery and fragile, tubular; spores 7–8 × 4 μ, hyaline, ellipsoid, smooth; basidia four-spored; cystidia not differentiated; pileus trama homogeneous; odor and taste not distinctive.

The third form (Pl. XXIII, Fig. 3) was found growing directly from the moss gametophytes much after the manner of *Omphalia Gerardiana* Pk. The description is of material collected in Rees' Bog, Cheboygan Co., Oct. 18, 1934 (1163). Pileus 12–20 (40) mm. broad, becoming broadly infundibuliform, disk broadly depressed at first, glabrous, hygrophanous, "bone-brown" to "fuscous" on the disk, "buffy brown" near the margin, fading to pale gray, when moist the striae conspicuous; flesh weak and fragile; lamellae narrow, close to subdistant, decurrent, concolorous with pileus; stipe 2 4 cm. × 1–2 mm., concolorous with the pileus, glabrous, base white-mycelioid at attachment; spores 6–7 × 4 μ, pileus trama homogeneous; cystidia not differentiated.

The writer at first was disposed to regard the second form as

distinct from the first. Mr. Carleton Rea, to whom specimens were submitted, was inclined to consider the second form *O. epichysium*, since Fries reported that species from humus as well as from decaying wood. Later during the season of 1934 the writer collected both forms and compared them in the fresh condition. No distinguishing characters could be discovered except the difference in habitat. The third form has the habit of *O. Gerardiana*, but in other respects the writer could not distinguish it from either of the other two. The third form seems to resemble *O. philonotis* very closely and may possibly be that species. Murrill considered *O. montana* Pk. to be the same as *O. epichysium*. *O. montana* is very probably the form found on humus.

Omphalia Gerardiana Pk. (Pl. XXIV, Fig. 1). — Since this species has been confused with *O. epichysium*, it seemed advisable to publish the photograph. For a description of the species see Kauffman, *Agaricaceae of Michigan*, p. 819. The spores of the writer's collections measure (6) 7–9 × 3.5–4 μ. This species is not ordinarily collected in abundance although from the writer's experience it is by no means rare. During the spring of 1934, however, it was a common species on sphagnum at Mud Lake Bog, Washtenaw Co.

Omphalia gracilis Quél. (= Agaricus, *Mycena immaculata* Pk., *Ann. Rep. New York State Mus.*, 38 : 41. 1885; *Mycena immaculata* (Pk.) Saccardo, *Syll. Fung.*, 5 : 264. 1887; *Omphalopsis immaculata* (Pk.) Murrill North Am. Flora, 9 : 312. 1916). — It is clearly evident from the descriptions of Bresadola (2) and Konrad and Maublanc (10) that the fungus known in America as *Mycena immaculata* (Pk.) Sacc. is the Omphalia described by Quélet. For a description of the American material see Kauffman, *Agaricaceae of Michigan*, p. 796.

Omphalia picta Fr. var. concolor Lange (Pl. XXV, Fig. 3). — Pileus 8–12 mm. broad, conic to campanulate, margin appressed against the stipe at first, surface covered by a grayish bloom when young, soon polished and lubricous, striate nearly to the apex, "fuscous" to "bone-brown" on the disk, margin grayish to brownish, striae fuligineous; gills distant or subdistant, moderately broad, arcuate and decurrent by a long tooth, glaucous gray or whitish, intervenose, edge even; stipe 2–4 cm.

× 1.5–2 mm., pale brownish gray to nearly white, glabrous, pruinose above; spores 6–7 × 3 μ, ellipsoid, smooth; basidia four-spored, 30–32 × 6–7 μ, cystidia 30–32 × 7–8 μ, apex roughened by short rodlike projections, on the edge only; pileus trama homogeneous, a few enlarged cells scattered near the surface.

Collected at Mud Lake Bog, Washtenaw Co., Nov. 3, 1933 (33–1147). As Lange has pointed out, this is not the typical form of the species. The writer's material corresponds exactly to Lange's description of the variety except for the slightly shorter stems.

PLEUROTUS TREMULUS Fr. — On moss and débris, Rees' Bog, Burt Lake, Oct. 9, 1934 (1112), and Oct. 18 (1162). Hesler (4) has recently reported this species from Tennessee and describes it well. Apparently the writer's collections form the first record of its occurrence in Michigan.

PLUTEUS CHRYSOPHAEUS Fr. — Pileus 2–3 cm. broad, campanulate, becoming expanded and abruptly umbonate, umbo usually rugose-reticulate, glabrous, dull "russet" to "Rood's brown," subhygrophanous and fading to "cinnamon-buff" or "cinnamon," margin striate when moist, often splitting radially in age; lamellae free, close, broad, white but changing to incarnate, oval in outline; stipe 3–5 cm. × 2–4 mm., white or sordid whitish gray, longitudinally fibrous-striate, solid at first, becoming tubular in large specimens; odor and taste slightly farinaceous; spores 5–7 × 5–6 μ, globose or broadly ellipsoid, flesh color in mass; cystidia on sides and edges of gills, 60–75 × 12–18 μ, fusoid-ventricose, not branched at apex; pileus trama with a surface layer of clavate to pyriform cells filled with a dark brown content, cells about 40 × 20 μ with a pedicel 18–20 × 5–6 μ, some cells in the layer were found to be elongated and cystidia-like.

Gregarious on old beech logs, Blisswood, Harbor Springs, Aug. 17, 1933 (33–648) and Dexter, Oct. 5 (33–1014). The striate margin and the cinnamon-brown pileus place the Michigan collections in this species. Mr. H. C. Beardslee, who has studied in detail the forms in this group, is also of the opinion that this fungus is *P. chrysophaeus*. It is identical with *P. admirabilis* Pk. in stature and structure, but differs typically in the color

of the cap. *P. phlebophorus* is said to be darker, with a more conspicuous rugose-reticulate nonstriate cap. The fungus described above is rather common throughout the state.

Psilocybe sarcocephala Fr. — Near the base of a tree, Ann Arbor, Sept. 30, 1934 (984). The pilei were hygrophanous, pale watery brown when moist and fading to buff, the flesh was rigid-cartilaginous and the gills a dull reddish brown. The spore print, however, is a true dull purplish brown. Konrad and Maublanc (10, Pl. 45) describe and illustrate the species as the writer has found it except that the spores in his collection measure 6–8 × 3–4.5 μ and are thus slightly smaller than the measurements given by the French investigators (7–9 × 3.5–5 μ).

Tricholoma pessundatum Fr. *sensu* Ricken. — Pileus 6–14 cm. broad, convex, broadly umbonate or the margin elevated, glutinous when fresh, "vinaceous" or "orange-cinnamon" on the disk, nearly white on the margin, not at all striate or hygrophanous; flesh thick, white; odor strongly farinaceous; taste bitter; lamellae close, narrow to moderately broad (5–6 mm.), sinuate, white, edge even or slightly broken, with reddish brown spots in age; stipe 4–8 × 1.2–2 cm., solid, with orange-brown fibrils below, apex pruinose, often with scattered brownish spots in age; spores 5–6 × 3 μ, smooth, ellipsoid; basidia 18–20 × 4 μ, four-spored; cystidia not differentiated; gill trama homogeneous, cells moderately long and somewhat interwoven; pileus trama with a differentiated gelatinous layer over the surface, floccose tissue below.

On needle beds under conifers, Saginaw Forest, Ann Arbor, Nov. 2, 1933 (33–1136), and Wilderness State Park, Emmet Co., Oct. 10, 1934 (1130). This species has been collected in the west by Kauffman, but apparently has not been reported from Michigan. At Wilderness Park it formed large arcs under the rather open stands of *Pinus resinosa*.

Tricholoma tumidum Fr. — On humus under oak trees, Ann Arbor, Oct. 14, 1932 (32–575), Nov. 2, 1933 (33–1134), and Nov. 28, 1934 (1172). This species has appeared regularly late in the fall in one locality for the last four years. It is a very fleshy but fragile species, and the pilei are usually broken as a result of being pushed up through the débris. In late fall it usually remains buried under the leaves and is easily overlooked. Kauff-

man in his unpublished notes mentioned that at times the fungus possessed a radish-like odor, and that the flesh often turned incarnate in age or when bruised. The writer's collections have repeatedly verified Kauffman's observations. At times water-soaked specimens may become dull reddish brown on both cap and stipe. In others the color change is very slight. The collections cited above somewhat resemble the variety *Kiethii* of Phillips and Plowright, but differ in possessing a radish-like odor rather than an odor of new meal and in growing in oak rather than in pine woods.

Tubaria pellucida (Fr. ex Bull.) Gillet *sensu* Konrad and Maublanc (10) (Pl. XXIV, Fig. 3).— Pileus convex to plane or slightly depressed, 8–40 mm. broad, "Hay's russet" to "cinnamon-rufous," hygrophanous, fading to "light vinaceous cinnamon" or "onion-skin pink," opaque to striate when moist, margin decorated with white patches from the veil, appressed-fibrillose to glabrous over the disk, lamellae broad, close to subdistant, adnate-decurrent, concolorous with pileus, edge slightly eroded; stipe 3–4 cm. × 3–4 mm., color of pileus but appearing paler because of the loose fibrillose covering, hollow, fragile; spores 7–9 × 4–5 μ, ellipsoid to slightly flattened on one side, pale ochraceous in mass; cystidia on gill edge only, 30–60 × 8–10 μ, clavate or with wavy outlines; gill trama homogeneous, interwoven, pileus trama homogeneous.

On sticks and débris in open woods and along roadsides, Stockbridge, Oct. 10, 1933 (33–1121; 33–1120); Ann Arbor, Nov. 28, 1934 (1168). Konrad and Maublanc (10) consider *T. pellucida* and *T. furfuracea* to be identical. Collections of the two have convinced the writer that the only difference is one of size and that alone is not a reliable character. The small form illustrated (Pl. XXV, Fig. 1) was found on sticks in a grassy woods road while the larger form was common on sticks in the woods. There seems to be little information concerning the species of this genus within the state. The fungus described above was rather common around Ann Arbor during the latter part of October and November in 1933 and 1934.

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LITERATURE CITED

1. Bisby, G. R., Buller, A. H. R., and Dearness, John. 1929. The Fungi of Manitoba. Longmans, Green and Co., Toronto.
2. Bresadola, J. 1928, 1929. Iconographia Mycologica, Fasc. VI and X.
3. Coker, W. C., and Beardslee, H. C. 1921. The Collybias of North Carolina. Journ. Elisha Mitchell Sci. Soc., 37 : 83–107.
4. Hesler, L. R. 1933. *Pleurotus tremulus* Fr. and *Secotium conicum* n. sp. Journ. Elisha Mitchell Sci. Soc., 49 : 151–155.
5. Kauffman, C. H. 1918. The Agaricaceae of Michigan. Lansing, Michigan.
6. —— 1925. The Genus Gomphidius in the United States. Mycologia, 17 : 113–126.
7. —— 1926. The Fungus Flora of Mt. Hood, with Some New Species. Pap. Mich. Acad. Sci., Arts and Letters, 5 (1925) : 115–148.
8. —— 1932. Cortinarius. North Am. Flora, 10 (Part 5) : 282–348.
9. —— and Smith, Alexander H. 1933. Agarics Collected in the Vicinity of Rock River, Michigan, in 1929. Pap. Mich. Acad. Sci., Arts and Letters, 17 (1932) : 153–200.
10. Konrad, P., et Maublanc, A. 1928–32. Icones Selectae Fungorum, Fasc. 4 and 7.
11. Kühner, R. 1930. Un Nouveau Groupe d'Agarics leucospores. Bull. Soc. Linn. Lyon, 9 : 67–69.
12. Lange, Jakob E. 1930. Studies in the Agarics of Denmark. Dansk Botanisk Arkiv, Bind 6, No. 5. Part VIII : 1–19.
13. Murrill, W. A. 1922. Dark Spored Agarics–II. Gomphidius and Stropharia. Mycologia, 14 : 121–142.
14. Smith, Alexander H., and Wehmeyer, L. E. 1936. Contributions to a Study of the Fungous Flora of Nova Scotia. II. Agaricaceae and Boletaceae. Pap. Mich. Acad. Sci., Arts and Letters, 21 (1935) : 163–197.

PLATES XVIII–XXV

Collybia palustris (Pk.) Smith, × 1

PLATE XIX

Gomphidius glutinosus Fr., × 1

Gomphidius viscidus f. *columbiana* Kauff., × 1

PLATE XXI

FIG. 1. *Galerula siliginea* (Fr.) Smith, × 1
FIG. 2. *Galerula capillaripes* (Pk.) Murr., × 1
FIG. 3. *Collybia ambusta* Fr., × 1

PLATE XXII

Fig. 1. *Omphalia detrusa* Fr., × 1
Fig. 2. *Omphalia epichysium* Fr., × 1

PLATE XXIII

FIGS. 1–3. *Omphalia epichysium* Fr., × 1

PLATE XXIV

Fig. 1. *Omphalia Gerardiana* Pk., × 1
Fig. 2. *Naucoria centuncula* Fr., × 1
Fig. 3. *Tubaria pellucida* (Fr. ex Bull.) Gillet, × 1

PLATE XXV

Fig. 1. *Tubaria pellucida* (Fr. ex Bull.) Gillet, × 1
Fig. 2. *Naucoria lubriciceps* Kauff. & Smith, × 1
Fig. 3. *Omphalia picta* Fr. var. *concolor* Lange, × 1
Fig. 4. *Dictyolus retirugis* (Fr.) Quél., × 1

CONTRIBUTIONS TO A STUDY OF THE FUNGOUS FLORA OF NOVA SCOTIA

II. AGARICACEAE AND BOLETACEAE *

ALEXANDER H. SMITH AND LEWIS E. WEHMEYER

INTRODUCTION

ALTHOUGH the province of Nova Scotia is perhaps one of the most favorable localities in North America for the study of fleshy fungi, very little is known of the agaric flora of the region. Previously, so far as the writers have been able to determine, only two hundred species and varieties in the Agaricaceae and forty-six in the Boletaceae have been reported for the province. During the summer of 1931, from the first part of July through the first week in September, the weather was particularly favorable for the development of fleshy forms, and an intensive study of them was made. As a result of this study and of some additional collections by the junior author in 1930 and 1933, the following list has been compiled. It contains twenty-five species in the Boletaceae, three of which are apparently first reports for the province, and three hundred and thirty-six species and varieties of the Agaricaceae, of which two hundred and seventeen are apparently first reports.

The list as published gives an accurate impression of the relative distribution of species within the genera of the Agaricaceae as they occurred in 1931. In the genus Cortinarius forty-four species are listed. This is only a fraction of the number of species which will eventually be found in this area, but, as their number indicates, the species of that genus were more numerous than those of any other. Although the period during which the work was carried on did not include the height of the season for species of Mycena, continued search yielded twenty-two species, many of which were of exceptional interest. The number of species of Russula and Lactarius was also notable. Species of certain genera, however,

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 473.

such as Hebeloma, Pleurotus, and Naucoria, were rare. The fact that collecting was not carried on late into the fall months, however, may account for much of this seeming rarity.

Certain species were quite abundant; *Amanita muscaria*, perhaps, leads the list. It was abundant when collecting began and reappeared in large numbers throughout the summer whenever weather conditions permitted it. *Tricholoma saponaceum* was frequently found on needle beds of spruce and fir, and was the only member of the genus which could be found regularly in 1931. *Lactarius helvus* was exceedingly common in bog areas, as was also *Pholiota caperata*.

A glance at the list shows that the majority of the species are those commonly found in both Europe and America. There are a number of reports, however, which are of particular interest in this connection. *Armillaria ventricosa*, which is supposed to be southern in its range, was found in considerable abundance under spruce and fir. *Cortinarius traganus* was rather common during the latter part of the season, but does not seem to have been reported previously in North America. *C. hircinus* and *C. triumphans*, two characteristically northern species, were well represented in the agaric flora. Both are considered very rare. *Pholiota trachyspora*, which, according to Overholts (12), is known only from the type locality in Colorado, was also collected. *Mycena quiniaultensis* Kauff. and *Gomphidius subroseus* Kauff. are two examples of species which were described from material collected on the Pacific Coast.

The collection numbers are those of the junior author. The collections have all been deposited in the University of Michigan Herbarium. Unless otherwise indicated, they were made by the senior author and in Colchester County. For a description of the localities in which the fungi were collected see Wehmeyer (19, p. 237).

LIST OF SPECIES

Species reported for the first time are marked with an asterisk.

AGARICACEAE

*Amanita bisporiger Atk. — Under hemlock, Upper Brookside, August 19, 1931 (798). Frequently seen after the middle of August and usually smaller than *Amanita verna*.

*Amanita brunnescens Atk. — On humus in coniferous woods, Salmon River, July 15, 1931 (631).

Amanita flavoconia Atk. — On humus in mixed woods, July, 1930 (143, 199), coll. L. E. W.; Upper Brookside, July 10, 1931 (603).

Amanita muscaria Fr. — On soil under spruce, Upper Brookside, June 28, 1931 (511); Upper Brookside, June 29, 1931 (524).

*Amanita porphyria Fr. — On humus in spruce woods, Upper Brookside, July 27, 1931 (705).

Amanita rubescens Fr. — On grassy places near spruce, 1930 (194), coll. L. E. W.; Upper Brookside, July 1, 1931 (542).

*Amanita solitaria Fr. — On humus under spruce, Upper Brookside, August 19, 1931 (797). A single perfect fruit body was found.

Amanita verna Fr. — On humus under hardwoods, Mt. Thom, August 15, 1931 (763).

Amanita virosa Fr. — On humus in mixed forest, Upper Brookside, August 12, 1931 (763a).

Amanitopsis vaginata Fr. var. alba Sacc. — In open woods of maple, Upper Brookside, August 14, 1931 (753).

Amanitopsis vaginata Fr. var. fulva Sacc. — On humus under beach and maple, Folleigh Lake, July 20, 1931 (685).

Amanitopsis vaginata Fr. var. livida Pk. — On humus in mixed woods, Victoria Park, Truro, 1930 (234), coll. L. E. W.; Victoria Park, Truro, July 4, 1931 (562).

*Armillaria adnatifolia (Pk.) Kauff. — On a dry slope under spruce, Upper Brookside, August 18, 1931 (779).

Armillaria mellea Fr. — On decaying stumps, Upper Brookside, September 3, 1931 (868).

Armillaria ventricosa Pk. — Gregarious, on humus under spruce, Salmon River, July 14, 1931 (644). Kauffman (6) questioned the occurrence of this species in Nova Scotia because it seems to have a southern distribution. We found the species to be abundant and typical in every respect. It develops slowly during favorable periods, and persists for a considerable length of time.

Armillaria viscidipes Pk. — Singly, under spruce and birch, Upper Brookside, July 25, 1931 (699). One large specimen was found; the odor was distinct, but the stipe was only slightly

viscid. There seems to be little doubt, however, that this is the fungus which Kauffman (6) collected in Colorado. The slight viscidity of the pileus, the buff or brownish color, the tendency to stain ochraceous, the spores, strong odor, and stature are distinct.

CANTHARELLUS AURANTIACUS Fr. — On débris in mixed forests of beech and fir, Upper Brookside, July 24, 1931 (703), coll. L. E. W. This usually common species was found but once.

CANTHARELLUS CIBARIUS Fr. — On humus in mixed woods, Upper Brookside, July 10, 1931 (598). Rather common.

*CANTHARELLUS CLAVATUS Fr. — Gregarious, on a hillside under spruce and fir, Upper Brookside, August 11, 1931 (732), coll. L. E. W.

CANTHARELLUS FLOCCOSUS Schw. — Gregarious, under spruce and fir, often covering large areas, Victoria Park, Truro, August 16, 1929 (224), coll. L. E. W.; Upper Brookside, July 7, 1931 (581). This is one of the most common species of the genus, and by far the largest; the vaselike fruit bodies were often 12–14 cm. broad and free from larvae. *C. cibarius* was widely distributed, but was not so abundant as *C. floccosus* in 1931.

CANTHARELLUS INFUNDIBULIFORMIS Fr. — Gregarious, under conifers, Upper Brookside (607); Earltown Road, August 21, 1931 (801).

*CANTHARELLUS LUTESCENS Fr. — Gregarious under spruce on swampy ground, Upper Brookside, August 11, 1931 (733), coll. L. E. W. Burt (1) has placed this species in Craterellus, where it may well belong. However, it is listed under the genus Cantharellus here because the hymenium, instead of being merely wrinkled, was formed by true gill-like ridges. An excellent illustration of the species is given in *Icones Farlowianae* (2).

*CLAUDOPUS VARIABILIS Fr. — On sticks and leaves, Upper Brookside, July 18, 1931 (667). This species is very abundant after periods of prolonged wet weather and can be found over wide areas; the small fruit bodies are attached to small sticks, leaves, or other bits of débris which happen to be lying on the forest floor.

*CLITOCYBE CONNATA (Schum.) Bres. — Around a very decayed stump, Earltown Road, August 21, 1931 (807).

*CLITOCYBE CYATHIFORMIS (Bull.) Fr. — Scattered, on an old beech log, Earltown Road, August 26, 1931 (824).

*Clitocybe decora Fr. — On a log, Folleigh Lake, July 20, 1931 (681).

Clitocybe ectypoides Pk. — On a coniferous log, Mt. Thom, August 15, 1931 (677a).

*Clitocybe gilva Fr. *sensu* Ricken. — Under fir on a moist grassy hillside, Upper Brookside, August 17, 1931 (764). The watery spots on the pileus, the globose echinulate spores, and the long-decurrent and narrow gills, as well as the yellowish tan pileus, serve to distinguish this species.

Clitocybe infundibuliformis Fr. — On soil, Upper Brookside, July 1, 1931 (549).

Clitocybe (laccaria) laccata Fr. — On the mossy bank of a stream, July 26, 1929 (171), coll. L. E. W.; Upper Brookside, June 27, 1931 (504).

*Clitocybe leptoloma Pk. At the base of a beech stub, Earltown Road, August 18, 1931 (787).

Clitocybe (laccaria) ochropurpurea Berk. — On soil, Upper Brookside, July 12, 1931 (652).

*Clitocybe odora var. anisearea Pk. — Under spruce, frequent, Upper Brookside, July 18, 1931 (653).

*Clitocybe piceina Pk. — Closely gregarious, on humus in a coniferous woods, Salmon River, September 7, 1931 (895).

*Clitopilus abortivus B. & C. — On hardwood débris, Upper Brookside, September 8, 1931 (896).

*Clitopilus albogriseus Pk. — On soil under conifers, Upper Brookside, July 17, 1931 (650).

*Clitopilus novaboracensis Pk. — On hardwood débris, Upper Brookside, August 14, 1931 (756), coll. L. E. W.

*Clitopilus orcella Fr. — Under spruce, Upper Brookside, August 18, 1931 (774).

Clitopilus prunulus Fr. — Under fir, Upper Brookside, July 7, 1931 (580); Upper Brookside, September 3, 1931 (580a). This species and *C. orcella* intergrade frequently. The forms listed here were separated chiefly on the character of the pileus surface, a distinctly viscid and a dry form being clearly recognizable.

Collybia acervata Fr. — On humus in a mixed woods, Upper Brookside, August 27, 1931 (828).

*Collybia alcalinolens Pk. — Upper Brookside, July 26, 1929 (128), coll. L. E. W.

COLLYBIA BUTYRACEA Fr. — On humus under spruce, Upper Brookside, July 18, 1931 (666).

*COLLYBIA CLUSILIS Fr. *sensu* Schroeter. — In a sphagnum bog, Upper Brookside, June 27, 1931.

*COLLYBIA CONFLUENS Fr. — On humus in mixed woods, Upper Brookside, July 18, 1931 (665). Rather frequent late in the summer.

COLLYBIA DRYOPHILA Fr. — On sphagnum, Upper Brookside, June 28, 1931 (512).

*COLLYBIA FAMILIA Pk. — On a moss-covered log, Earltown Road, August 21, 1931 (800).

*COLLYBIA MYRIADOPHYLLA Pk. — On a moss-covered log, Earltown Road, August 21, 1931 (804).

COLLYBIA PLATYPHYLLA Fr. — Coll. L. E. W., 1930 (95).

COLLYBIA RADICATA Fr. — On soil, coll. A. R. Prince, 1930 (129); Upper Brookside, July 8, 1931 (589).

COLLYBIA RADICATA Fr. var. FURFURACEA Pk. — On soil, Truro, July 15, 1931 (630), coll. Mrs. L. E. Wehmeyer.

COLLYBIA RADICATA PUSILLA Pk. — On humus, Mt. Thom, August 15, 1931 (758).

*COLLYBIA TUBEROSA Fr. — On old fungous remains, Salmon River, August 13, 1931 (748).

COPRINUS MICACEUS Fr. — On soil, Upper Brookside, September 9, 1931 (897).

*COPRINUS MISER Karst. — On rabbit dung, New Glasgow Road, June 30, 1931 (527).

COPRINUS PLICATILIS Fr. — On lawn, Truro, July 9, 1933 (1577), coll. L. E. W.

*CORTINARIUS ACUTUS Fr. — Gregarious, on moss under spruce, Upper Brookside, September 5, 1931 (885).

*CORTINARIUS ANNULATUS Pk. — On humus in a mixed forest of beech and spruce, Folleigh Lake, August 29, 1931 (842).

CORTINARIUS ANOMALUS Fr. — Gregarious, on humus in a beech woods, Salmon River, August 18, 1931 (770).

CORTINARIUS ARMILLATUS Fr. — Very common in mixed forests after the middle of August, Salmon River, August 13, 1931 (742).

*CORTINARIUS BOLARIS Fr. — On humus and débris in a mixed forest, Earltown Road, August 21, 1931 (781). One of the most striking species of the genus but found only in the one locality.

CORTINARIUS CANINUS Fr. — Gregarious, on humus, Upper Brookside, September 5, 1931.

CORTINARIUS CASTANEUS Fr. — Gregarious, under spruce on a mossy hillside, Upper Brookside, September 6, 1931 (891).

*CORTINARIUS CHRYSOLITUS Kauff. — Singly, on sphagnum, Salmon River, August 13, 1931 (744). The spores of this collection average 7–8 × 4–5 μ, but otherwise the specimens fit the description as given by Kauffman (7). There was no odor or taste, and the spores were not subglobose.

CORTINARIUS CINNAMOMEUS Fr. — On humus under spruce, gregarious, rather frequent, Upper Brookside, July 8, 1931 (582).

*CORTINARIUS CORRUGATUS Pk. — On humus in a beech-maple forest, Folleigh Lake, July 10, 1931 (669). Found but once. The pilei were 5–10 cm. broad, "ochraceous orange" [1] to "zinc-orange," fading to "ochraceous buff," and the surface was very corrugated. The lamellae were "pale violet-gray" when young, close, and with eroded edges. The stipe was scarcely bulbous.

*CORTINARIUS CYLINDRIPES Kauff. — Singly, under fir and spruce, Salmon River, July 3, 1931 (556). Not common.

*CORTINARIUS DILUTUS Fr. — Gregarious, on humus in a mixed forest of beech and fir, Upper Brookside, September 3, 1931 (863). Kauffman (7) has reported this species from the Adirondacks, Rocky Mountains, Olympic Mountains, and Mt. Hood. It is apparently rather rare.

*CORTINARIUS DURACINUS Fr. — Scattered, on moss under spruce and fir, Upper Brookside, September 6, 1931 (892).

*CORTINARIUS ERYTHRINUS Fr. — Gregarious, on humus under maple, birch, and hemlock, Upper Brookside, September 5, 1931 (883).

*CORTINARIUS EVERNIUS Fr. — Gregarious, on sphagnum, not infrequent, Upper Brookside, July 13, 1931 (614).

*CORTINARIUS FIRMUS Fr. — On grassy soil in an open woods of spruce, Upper Brookside, September 5, 1931 (888). The following description is of collection No. 888: Pileus 9–14.5 cm. broad, convex, becoming plane or slightly depressed in age, color varying near "ochraceous tawny," "tawny," "russet," or "cinnamon-brown," lighter when young, darker in age, glabrous but

[1] All color names in quotation marks are taken from R. Ridgway, *Color Standards and Color Nomenclature*, Washington, D.C., 1912.

appearing appressed-fibrillose under a lens, in age appearing somewhat variegated, neither hygrophanous nor viscid; flesh thick and firm, pallid brownish; lamellae pallid or pale brown when young, becoming pale cinnamon in age, edge rather uneven, close, broad (6–9 mm.), shallowly adnexed to deeply and narrowly adnexed; stipe 3–6 cm. long, 3–4 cm. thick, very short and broad, whitish over all at first but lower portion soon rather sordid, remaining white and pruinose-fibrous above, solid, flesh pallid; cortina white, scanty; spores 7–8 × 4 4.5 μ, pale brown under the microscope; sterile elements in hymenium basidia-like with dark brown contents, 30–35 × 6–7 μ.

Although the specimen was collected during weather which was exceptionally favorable for the development of agarics, the pileus was not at all hygrophanous. This fact distinguishes the species from the closely related *Cortinarius subferrugineus*. The illustration of Cooke depicts the Nova Scotia collection accurately in stature, but the colors of the stipe are darker than those observed in our collection.

*Cortinarius herpeticus Fr. — Gregarious, on a wet hillside under spruce and fir, Earltown Road, August 18, 1931 (780).

*Cortinarius hircinus Fr. — Gregarious, under spruce and fir, Upper Brookside, September 5, 1931 (882); Upper Brookside, September 6, 1931 (882a). This is a striking species, but apparently rare in North America. Kauffman collected it at Seventh Lake in the Adirondacks on September 5, 1921. His collection apparently is the first record of the species in North America. A description of the Nova Scotia collections follows. Pileus 6 8 cm. broad, broadly conical to convex, plane in age, "pallid Quaker drab" when young or with more of a purplish tinge, becoming tawny in age, surface appressed-silky, often with brownish fibrous patches near the margin, disk sometimes cracked into areolate patches or tending to become scabrous, neither hygrophanous nor viscid; lamellae when young "mauve," soon becoming a dull bluish purple but changing to "dark grayish lavender" as the pileus expands and remaining this color until the maturing spores mask it with cinnamon-brown, close, about 1 cm. broad, rounded and deeply but narrowly adnexed, edge minutely eroded-crenulate; stipe 6-9 cm. long, 1–1.5 cm. thick, base clavate and 25 30 mm. thick, flesh colored like the young

lamellae or paler, almost whitish in the bulb, surface white-fibrillose from the universal veil, subannular patches often present, appressed fibrous-striate above the cortina; spores 8–10 × 5 μ, ellipsoid, rough punctate; odor very intense and very disagreeable, resembling somewhat that of rotten potatoes. The odor from our collections was strong enough to be detected anywhere in the room in which the specimens were lying.

Our collections differed slightly from the description as given by Ricken in that the young gills were not quite reddish violet and that this early color was not persistent. The spores were slightly shorter, the gills were a little broader, possessed a decurrent tooth, and were not crisped.

*Cortinarius infractus Fr. — Gregarious, on humus under spruce and fir, Earltown Road, August 26, 1931 (823); Upper Brookside, August 27, 1931 (823a).

*Cortinarius iodes B. & C. — Closely gregarious, under second-growth hard maple, Upper Brookside, September 4, 1931 (874); Upper Brookside, September 8, 1931 (874a). The spores of No. 874 measure 7–8 × 4–5 μ, while those of No. 874a measure 8–10 × 6–6.5 μ. No other differences were found which could be correlated with the spore sizes.

*Cortinarius juberinus Fr. — On swampy ground under spruce, Upper Brookside, July 1, 1931 (574); Earltown Road, August 18, 1931 (574a).

Cortinarius lilacinus Pk. — On swampy ground under spruce, Upper Brookside, July 24, 1931 (702).

*Cortinarius lucorum Fr. — Gregarious, in wet upland woods, Upper Brookside, August 27, 1931 (833).

*Cortinarius malicorius Fr. — On humus and needles under spruce and fir, gregarious, uncommon, Upper Brookside, August 27, 1931 (838); Upper Brookside, September 6, 1931 (831).

*Cortinarius Morrisii Pk. — Gregarious, in mixed woods, Earltown Road, August 26, 1931 (825); Earltown, August 26, 1931 (825a).

Cortinarius mucifluus Fr. — Scattered, under spruce, not uncommon, Upper Brookside, August 27, 1931 (836).

*Cortinarius multiformis Fr. — On humus in mixed woods, scattered, Upper Brookside, September 6, 1931 (890).

*Cortinarius nigrellus Pk. — Scattered over a small area under

hardwoods, Upper Brookside, August 31, 1931 (845); Folleigh Lake, August 29, 1931 (845a).

*Cortinarius pholideus Fr. — Gregarious, under fir and beech, Upper Brookside, September 3, 1931 (861).

*Cortinarius plumiger Fr. — Widely gregarious, under fir and beech, Upper Brookside, September 3, 1931 (861). The densely fibrillose-tomentose or fibrillose-hairy pileus with the patches of the universal veil clinging to the margin and the very copious cortina are characteristic of this species. The stipe also is usually covered by annular patches from the universal veil, which are whitish at first but become brownish in age. The flesh is quite watery-punctate, a characteristic of hygrophanous species, but the fibrillose-hairy covering of the pileus is so dense that the characteristic fading can hardly be noticed, and one is more likely to look among the species of Inoloma than in Telamonia for a description of his collection.

*Cortinarius salor Fr. — On humus under maple and beech, Upper Brookside, August 27, 1931 (850); Upper Brookside, September 6, 1931 (830a). This species differs from *C. iodes* in the shape of the spores as well as in size. In No. 830a the spores measured 6–7.5 × 5.5–6 μ; those of No. 830 measured 6.5–8 × 5.5–6 μ. The shape is very broadly ellipsoid to subglobose. In *C. iodes* the spores are distinctly narrower as compared with their length. Konrad (8) describes the species well, but gives the spore size as 8–9 × 7–8 μ and the gills as broad and adnexed-emarginate. In our specimens the gills were adnate and only moderately broad. The colors of the pileus, the innate fibrils on the pileus in age, and the subglobose to very broadly ellipsoid spores place our plants in this species.

Kauffman, in 1903, collected a plant near Ithaca, New York, with spores 7.5–9 × 7.5–8 μ, which clearly belongs in this group of species. It is without doubt *C. salor*. The distribution of this species in North America should include Nova Scotia and New York.

Cortinarius sanguineus Fr. — Gregarious, on humus under spruce, Folleigh Lake, August 29, 1931 (843), coll. L. E. W.; Upper Brookside, August 31, 1931 (843a).

*Cortinarius scutulatus Fr. *sensu* Kauffman. — Gregarious, under spruce, Upper Brookside, September 3, 1931 (865).

CORTINARIUS SEMISANGUINEUS (Fr.) Kauffman. — On soil under conifers, Upper Brookside, July 4, 1931 (560).

*CORTINARIUS SPHAEROSPORUS Pk. — On humus under spruce, on a wet hillside, solitary, Earltown Road, August 18, 1931 (782). The spores of this collection measured 6.5–7.5 × 5–6.5 μ, and were nearly smooth.

*CORTINARIUS SQUAMULOSUS Pk. — Singly, under second-growth hardwoods, Upper Brookside, August 31, 1931 (845); Upper Brookside, September 7, 1931 (845a).

*CORTINARIUS SUBFLEXIPES Pk. — On soil under maple and beech, Upper Brookside, September 1, 1931 (854). The spores of this collection average 7.5–8.5 (9) × 4–5 μ and are distinctly roughened. Macroscopically the plants fit Kauffman's description very well.

*CORTINARIUS SUBMARGINALIS Pk. — On humus under hardwoods, Upper Brookside, September 2, 1931 (856). Pileus 6–9 cm. broad, convex, with a definite decurved margin about 5 mm. broad, bearing scanty fibrillose remains of a veil, "yellow ochre" to "ochraceous tawny" on the disk, margin "warm buff" or "light buff"; flesh whitish to brownish, very pale; lamellae adnate or broadly emarginate, pale yellow but soon brown from the spores, close, broad; stipe 6–11 cm. × 1–2 cm., equal or slightly narrowed at the base, pallid, becoming brownish after handling, viscid, solid, not marked by concentric sheaths; spores 10–12.5 × 5–6.5 μ, almond-shaped, very rough. Peck's figure (15) shows a plant with an equal stipe, and a pileus with scanty fibrillose remnants scattered along a rather broad margin. Kauffman groups this species among those with clavate stems. The stems in our plants were strictly equal or narrowed toward the base. Since our collection agrees well with Peck's description and figures it is referred there without hesitation.

*CORTINARIUS SUBPULCHRIFOLIUS Kauff. — Scattered, under hemlock and birch, Salmon River, August 18, 1931 (771).

CORTINARIUS SUBPURPURASCENS Fr. — Gregarious to subcespitose, under spruce and fir, Upper Brookside, August 18, 1931 (791); Earltown Road, August 22, 1931 (791a). Common after rainy periods in July and August. The smaller spores (7.5–9 × 4.5–5 μ), brownish colors, less pronounced change to purplish where cut or bruised, gregarious-to-subcespitose habit, and its habitat,

place our collection here rather than in *C. purpurascens* Fr. The stems, however, were solid.

*Cortinarius traganus Fr. — Frequent under fir and spruce, Upper Brookside, August 31, 1931 (849); Upper Brookside, September 3, 1931 (849a). Apparently this species has not been previously reported in North America. A description of the American collections follows: Pileus 4–11 cm. broad, convex, obtusely umbonate, becoming plane, "light mauve" to "pale mauve" over all, fading to whitish or even ochraceous on the disk when quite dried out, surface dry, appressed-fibrillose, margin with remnants of veil, matted fibrils subviscid when moist, no true pellicle present; flesh "light buff" in the pileus, somewhat ochraceous in age, thick, spongy; lamellae dull lilac, becoming "buckthorn-brown" very early (before the veils are broken), in age "ochraceous tawny" to "tawny" from the spores, close in unexpanded specimens but subdistant in those which are well developed, edge even, adnate at first, slightly sinuate in age, broad, not ventricose; stipe 6–10 × 1–3 cm., clavate-bulbous at first, becoming nearly equal when the fruit body is expanded, covered by a copious layer of fibrils which are colored like those on the pileus, apex paler but fibrillose, the fibrils hanging in loose patches along the stipe, becoming white in age; flesh of stipe "warm buff," spongy; spores 7.5–9 × 5–5.5 μ, ellipsoid, slightly roughened.

Aside from the pale color, Ricken's (17) figure represents our plant remarkably well. There is a discrepancy, however, in the color of the young gills. In our plants the very small buttons possessed sordid lilac gills, but long before the spores began to form and long before the veils broke the color changes described above took place. Since all the other characteristics were remarkably well represented, it seems best to assign our collections to this species. Spores from material collected in Sweden by Kauffman are identical in size and markings with the spores of our specimens. This species begins to appear as early as the first of July, but does not develop properly until after the heavy fall rains. Clumps of the unexpanded buttons were a rather common sight on hillsides under spruce and balsam during August.

*Cortinarius triumphans Fr. — Gregarious, under conifers, Upper

Brookside, September 1, 1931 (851). The spores measure 10–12 × 5–6 μ. This is slightly smaller than the size given by Kauffman (7), but checks exactly with the measurements of Ricken (17). An examination of the specimens preserved in the University of Michigan Herbarium indicates that the size, as well as the tuberculate markings on the spores, varies. Although this species is reported as rare, it was not infrequent at Upper Brookside during the early part of September.

*Cortinarius vibratilis Fr. — Singly, on mossy ground under conifers, Upper Brookside, July 24, 1931 (698); Earltown Road, August 21, 1931 (698a). The fruit bodies of the Upper Brookside collection were exceptionally large, the pilei measuring 6–10 cm. broad, and the stems 6–15 cm. × 12–20 mm. The collection from Earltown, however, was typical.

Cortinarius violaceus (L.) Fr. — Singly, under spruce and fir, Killag Mines, Halifax County, July 30, 1931 (713); Salmon River, August 13, 1931 (713a).

*Cortinarius Whitei Pk. — Gregarious, in mixed conifer and hardwood forests, Mt. Thom, August 15, 1931 (761). In this collection the pilei were colored "burnt sienna" or "Kaiser brown" when moist, but faded to orange or "ochraceous orange," finally becoming "ochraceous tawny." The gills were "yellow ocher" when young becoming "amber-brown" at maturity. The stipe was yellow ocher above, more reddish near the base, and slightly lighter than the pileus when the latter was moist.

*Crepidotus applanatus Fr. — On beech logs, Folleigh Lake, July 20, 1931 (683); New Glasgow Road, July 25, 1931 (683a). The spherical spores and the narrow tapering decurrent gills mark this species.

*Crepidotus haerens Pk. — On wood of deciduous trees, New Glasgow Road, June 30, 1931 (513).

Crepidotus stipitatus Kauff. — On beech débris, Mt. Thom, August 10, 1931 (731); Mt. Thom, August 10, 1931 (731a), coll. L. E. W. The pilei were white when collected, but their watery consistency caused them to become a dirty watery gray after being handled. Upon drying the color changes to "ochraceous tawny." The stipe was well developed in some specimens, the villose tuft on the pileus just above the stem was distinct, and the spores were spherical.

*Crepidotus versutus Pk. — On beech, Folleigh Lake, July 20, 1931 (682).

*Eccilia atrides Fr. — Gregarious, on humus under hardwoods, Folleigh Lake, July 20, 1931 (680).

*Eccilia rhodocylix Lasch. — On an old stump, New Glasgow Road, July 25, 1931 (704). The spores of our specimens measure 11–13 × 6-7.5 μ with the apiculus. This species is distinguished by the brownish hygrophanous pilei, which fade to whitish in age, the distant, rather thick lamellae which are white at first but soon become a delicate pink, and the gray stipe.

*Eccilia roseoalbocitrina Atk. — On humus under hardwoods, Folleigh Lake, July 20, 1931 (676). Pileus pure white, appressed-fibrillose to silky, becoming slightly scaly in age and tinged flesh color when the spores mature, subhygrophanous, margin very wavy to coarsely crenate; lamellae white, then flesh color, adnate but with a pronounced decurrent tooth; stipe 4–6 cm. × 2–3 (4) mm., cartilaginous, very fragile, tubular, pure white; spores quite variable, about 9–11 × 6–9 μ; odor spicy or fragrant, very pronounced.

*Entoloma cuspidatum Pk. — On wet humus under hardwoods, Folleigh Lake, July 20, 1931 (673); Earltown Road, August 18, 1931 (673a). A very striking species reminding one of certain species of Hygrophorus. The spores, however, are distinctive.

*Entoloma cyaneum Pk. — Singly, on humus in a beech-maple forest, Earltown Road, August 22, 1931 (813).

*Entoloma grande Pk. — Gregarious, under fir, Upper Brookside, July 7, 1931 (579); Upper Brookside, August 28, 1931 (579a). Pileus 4–7.5 cm. broad in No. 579 and 10–20 cm. in No. 579a, "cartridge-buff" to "ivory-yellow" or whitish, yellowish or brownish tints predominating, neither viscid nor hygrophanous, cuticle adnate, often cracking into various patterns when drying, fleshy, hemispherical when young, convex to nearly plane in age, scarcely umbonate; flesh thick, white; odor and taste farinaceous; lamellae concolorous, narrow or broad (2 cm. broad in the largest specimen), close, sharply emarginate, seceding; stipe 5-7 cm. × 1–2 cm., equal, floccose to scaly near the apex, nearly glabrous below, concolorous, solid, not stuffed; spores 8–10 × 7–9 μ, angular, subglobose; cystidia not seen, sterile cells of the ventricose, elongating type.

*Entoloma griseum Pk. — Gregarious, on moist soil, Princeport, July 9, 1931 (595).

*Entoloma lividum Fr. — On humus under spruce and fir, Upper Brookside, September 4, 1931 (872).

*Entoloma luteum Pk. — Singly, under beech and maple, Killag Mines, Halifax County, July 30, 1931 (715); Earltown Road, August 22, 1931 (715a). Pileus 2–3.5 cm. broad, 2–2.5 cm. high, evenly conical to campanulate, "yellow ocher" to "buckthorn-brown" (the yellow seems to form the ground color and the brown tends to give the pileus a streaked appearance), neither viscid nor hygrophanous, tending to be more or less fibrous; lamellae adnate, whitish at first, then yellowish near the margins, finally flesh color from the spores, subdistant to close, edge eroded, ventricose; stipe 8–10 cm. long, 5 mm. thick, concolorous, whitish at the apex, hollow, pallid within, striate, glabrous or with fibrillose striations similar to those on the pileus; spores consistently quadrate, 9–12 μ; taste very bitter but not lasting. This species is easily distinguished but seems to be rare.

*Entoloma madidum Fr. — Singly, on humus in a forest of spruce, fir and beech, Earltown Road, August 22, 1931 (812).

*Entoloma salmoneum Pk. — Scattered, on humus under hardwoods, Earltown Road, August 18, 1931 (786). A very striking species, resembling *E. cuspidatum* in texture and stature. The largest fruit bodies in our collection measured 5 cm. broad and 11 cm. high. The bright salmon color distinguished this species from *E. cuspidatum*, which was always found to be a pale waxy yellow. Both species were growing in the same locality at Earltown, and in considerable abundance, thus enabling a careful comparison in the field. No intergrading forms were found.

*Entoloma sericatum Britz. — On needles under spruce, Victoria Park, Truro, July 23, 1931 (693); Upper Brookside, August 17, 1931 (693a); New Glasgow Road, July 25, 1931 (693b).

*Entoloma sericellum Fr. — Scattered, under hardwoods, Upper Brookside, August 21, 1931 (808). The pilei measured up to 25 mm. broad, the stems 5–10 cm. × 2–4 mm.

*Flammula decorata Murr. — On moss and débris, Salmon River, July 15, 1931 (636).

*Flammula lenta Fr. — On buried sticks of birch, Earltown Road, August 18, 1931 (785).

*Flammula spumosa Fr. — On conifer wood, Salmon River, August 25, 1931 (819); Upper Brookside, August 27, 1931 (831).

*Gomphidius maculatus Fr. — Under spruce and fir, Upper Brookside, July 28, 1931 (708).

*Gomphidius subroseus Kauff. — Under conifers in a boggy area, Upper Brookside, August 31, 1931 (848).

Hebeloma crustuliniforme Fr. — On humus among beech and maple, Upper Brookside, September 11, 1931 (853).

*Hygrophorus borealis Pk. — In mixed woods, Upper Brookside, September 7, 1931 (882).

*Hygrophorus ceraceus Fr. — On humus under beech and maple, Folleigh Lake, July 20, 1931 (678).

Hygrophorus chlorophanus Fr. — Under beech on bare soil, Upper Brookside, June 28, 1931 (515); Upper Brookside, June 29, 1931 (515a).

Hygrophorus conicus Fr. — Gregarious, on humus in mixed woods, Upper Brookside, July 18, 1931 (659); Upper Brookside, July 20, 1931 (695a).

Hygrophorus eburneus Fr. — Scattered, under spruce, Upper Brookside, September 3, 1931 (866).

*Hygrophorus marginatus Pk. — Singly, on humus under maple, Upper Brookside, July 18, 1931 (661); Upper Brookside, July 22, 1931 (661a).

Hygrophorus miniatus Fr. — Common, on soil and humus in mixed woods, Upper Brookside, July 16, 1931 (651); Upper Brookside, July 17, 1931 (651a).

*Hygrophorus nitidus B. & C. — On humus in coniferous woods, Salmon River, July 15, 1931 (632).

*Hygrophorus Peckii Atk. — On soil and humus under fir, spruce, beech and hemlock, common, Upper Brookside, July 4, 1931 (565).

*Hygrophorus pratensis Fr. — In mixed woods of beech and hemlock, Upper Brookside, July 18, 1931 (668).

*Hygrophorus pratensis var. pallidus Kauff. — In a hayfield near deciduous trees, Upper Brookside, August 18, 1931 (778).

*Hygrophorus psitticinus Fr. — Singly, on humus in mixed woods, Upper Brookside, July 18, 1931 (660).

Hygrophorus puniceus Fr. — Scattered, on humus in mixed woods, Upper Brookside, August 22, 1931 (814).

*Hygrophorus russula (Fr.) Kauff. — Singly, under maple and beech, Upper Brookside, August 27, 1931 (835).

Hygrophorus unguinosus Fr. — Under spruce, Upper Brookside, September 4, 1931 (875). A rare species, distinguished by the white gills, which are in striking contrast to the dark color of the remainder of the fruit body, the viscidity, and the spore size.

*Hypholoma hydrophilum Fr. *sensu* Ricken. — At the base of a beech stump, Upper Brookside, September 2, 1931 (859). Infrequent but usually occurring in large numbers when found.

*Hypholoma incertum Pk. var. sylvestris Kauff. — Singly, on débris of deciduous trees, Upper Brookside, July 8, 1931 (592), coll. L. E. W.

Hypholoma sublateritium Fr. — Found growing abundantly around old stumps of beech and maple, Upper Brookside, June 28, 1931 (541).

*Inocybe calamistrata Fr. — On soil, under spruce, July 4, 1931 (570).

*Inocybe cincinnata Fr. — On sandy soil, Folleigh Lake, August 29, 1931 (844).

*Inocybe eutheles var. palidipes (E. & E.) Heim. — On bare soil, Upper Brookside, July 3, 1931 (557).

*Inocybe fastigiata Fr. — On sandy soil, Upper Brookside, June 27, 1931 (510); Upper Brookside, July 13, 1931 (612); Upper Brookside, July 18, 1931 (664); Upper Brookside, August 12, 1931 (510a).

*Inocybe geophila var. violacea f. lilacina (Fr.) Heim. — On mossy hillside, Upper Brookside, August 26, 1931 (820).

*Inocybe hystrix Fr. — On humus in spruce woods, Upper Brookside, August 18, 1931 (773).

*Inocybe lacera Fr. — On soil in an old road, Upper Brookside, July 3, 1931 (558); Upper Brookside, August 27, 1931 (834).

*Inocybe lanuginosa f. longicystis (Atk.) Heim. — On an old log, Salmon River, July 15, 1931 (633).

*Inocybe leptophylla Atk. — On very rotten wood and débris, probably coniferous, July 1, 1931 (543); Upper Brookside, July 27, 1931 (543a).

*Inocybe nodulosa Kauff. — On soil in coniferous woods, New Glasgow Road, June 30, 1931 (532); Upper Brookside, July 6, 1931 (532a).

*Inocybe prominens Kauff. — On soil in coniferous woods, Upper Brookside, July 3, 1931 (559); Upper Brookside, July 8, 1931 (583).

*Inocybe sambucella Atk. — Mixed woods, Upper Brookside, July 10, 1931 (599).

*Inocybe subochracea (Pk.) Earle. — On a bare bank in a ravine, Upper Brookside, July 9, 1931 (596); Upper Brookside, July 11, 1931 (596a).

*Inocybe vatricosa Fr. — On moist soil, Upper Brookside, August 17, 1931 (766); Upper Brookside, August 18, 1931 (766a).

*Inocybe virgata Atk. — On humus in mixed woods, Upper Brookside, September 4, 1931 (873).

*Lactarius aspideoides Burl. — Gregarious, under conifers, Upper Brookside, August 18, 1931 (790).

*Lactarius camphoratus Fr. — On mossy bank, Victoria Park, Truro, August 16, 1929 (241), coll. L. E. W.; Upper Brookside, July 14, 1931 (619).

Lactarius cheledonius Pk. — Scattered, on grassy hillsides under or near spruce, Upper Brookside, August 17, 1931 (767), coll. L. E. W.

*Lactarius colorascens Pk. — On moss and needles under spruce, Upper Brookside, August 13, 1931 (745).

Lactarius deliciosus Fr. — In low swampy woods of spruce and fir, Upper Brookside, July 24, 1929 (157), coll. L. E. W.; Upper Brookside, July 4, 1931 (563); Salmon River, August 17, 1931 (563a).

*Lactarius fuliginosus Fr. — Scattered, under conifers usually on moist hillsides, Upper Brookside, August 18, 1931 (775).

*Lactarius glyciosmus Fr. — Under conifers, Upper Brookside, August 31, 1931 (850).

*Lactarius griseus Pk. — Gregarious, on mossy hummocks in coniferous woods, Upper Brookside, July 13, 1931 (615).

*Lactarius helvus Fr. — Scattered over large areas, in sphagnum bogs, Salmon River, August 13, 1931 (746). A very common species in sphagnum bogs, but never observed in any other habitat. The odor is very pronounced in the dried specimens.

*Lactarius hygrophoroides B. & C. — In the grass along an old logging road through a beech-maple forest, Killag Mines, Halifax County, July 30, 1931 (716).

LACTARIUS LIGNYOTUS Fr. — Under fir in sphagnum on a moist hillside, Upper Brookside, July 13, 1931 (613). This is a rather rare species whereas *L. fuliginosus* is quite common. They seem to intergrade considerably. Typical specimens of *L. lignyotus* were found only in sphagnum while *L. fuliginosus* was quite common on various substrata under conifers.

*LACTARIUS LUTEOLUS Pk. — Gregarious, under hardwoods and along old roads, Killag Mines, Halifax County, July 30, 1931 (714).

LACTARIUS PIPERATUS Fr. — On humus in mixed woods, Victoria Park, Truro, 1930 (243), coll. L. E. W.

*LACTARIUS PUBESCENS Fr. *sensu* Bres. — Under hemlock, Upper Brookside, August 12, 1931 (737).

*LACTARIUS REPRESENTANEUS Britz. — Under conifers, Upper Brookside, August 18, 1931 (789); Upper Brookside, August 25, 1931 (789a).

*LACTARIUS RESIMUS Fr. — Under conifers, Upper Brookside, September 4, 1931 (877).

LACTARIUS SCROBICULATUS Fr. — Under hemlock, Upper Brookside, August 12, 1931 (735); August 28, 1931 (735a).

LACTARIUS SUBDULCIS Fr. — On humus in mixed forest, Upper Brookside, August 18, 1931 (776).

*LACTARIUS SUBVELLEREUS Pk. — On humus under spruce and fir, Upper Brookside, September 3, 1931 (867).

*LACTERIUS THIOGALUS Fr. — On humus in mixed woods of hemlock, beech, and maple, Upper Brookside, August 22, 1931 (815).

LACTARIUS TORMINOSUS Fr. — On humus under spruce, Upper Brookside, August 11, 1931 (777).

*LACTARIUS TRIVIALIS Fr. — On humus under hardwoods, Upper Brookside, July 7, 1931 (577).

*LACTARIUS TRIVIALIS Fr. var. VIRIDILACTIS Kauff. — Under hemlock, Upper Brookside, July 13, 1931 (611); Salmon River, August 13, 1931 (611a).

*LACTARIUS TURPIS Fr. — Scattered, under hardwoods, Earltown Road, August 18, 1931 (784).

LACTARIUS UVIDUS Fr. — Widely gregarious, under conifers, September 4, 1931 (871).

LACTARIUS VELLEREUS Fr. — Scattered, under hardwoods, Killag Mines, Halifax County, July 30, 1931 (718).

Lentinus cochleatus Fr. — On beech, Earltown Road, August 26, 1931 (822).

*Lepiota clypeolaria Fr. — Under spruce, Salmon River, August 1, 1931 (720); Victoria Park, Truro, August 17, 1931 (720a).

Lepiota cristata Fr. — On humus, Earltown Road, August 21, 1931 (803).

*Lepiota fuscosquamea Pk. — Under spruce, Upper Brookside, August 19, 1931 (792); Upper Brookside, September 4, 1931 (792a). The small spores (6–8 × 3–4 μ), the reddish brown scales on the pileus, and the stature distinguish this species. When young and moist the pileus is a blackish brown, but the cuticle soon breaks, and the color fades somewhat.

Lepiota glioderma Fr. — On humus under hardwoods, Earltown Road, August 21, 1931 (802).

*Lepiota naucina Fr. — Singly, in meadows, Upper Brookside, September 11, 1931 (899).

Lepiota procera Fr. — Singly, near stumps in an old pasture, Upper Brookside, August 8, 1931 (763).

*Leptonia asprella Fr. — Under beech, Upper Brookside, July 17, 1931 (648).

*Leptonia formosa Fr. — On humus in mixed woods, Upper Brookside, July 17, 1931 (649).

Leptonia lampropoda Fr. — Gregarious, on humus under hardwoods, Earltown Road, August 22, 1931 (810).

*Marasmius androsaceus Fr. — Scattered, on needles, Upper Brookside, June 27, 1931 (506).

Marasmius cohaerans (Fr.) Bres. — Among leaves of beech and maple, Upper Brookside, September 2, 1931 (856).

*Marasmius foetidus Fr. — On sticks of frondose wood, Upper Brookside, July 11, 1931 (606).

Marasmius oreades Fr. — On grassy ground, Truro, 1930 (250), coll. L. E. W.; Upper Brookside, July 24, 1931 (697).

*Marasmius rotula Fr. — In beech and maple woods, also under conifers, Upper Brookside, June 27, 1931 (507); Upper Brookside, July 7, 1931 (56), coll. L. E. W.

*Marasmius scorodonius Fr. — On leaves and sticks, Upper Brookside, July 22, 1931 (689).

*Marasmius siccus (Schw.) Fr. — Among leaves, Upper Brookside, July 23, 1931 (692).

*Mycena alcalina Fr. — Scattered, on débris in a frondose wood, Upper Brookside, July 18, 1931 (657).

*Mycena atroumbonata Pk. — Subcespitose to gregarious, on beech logs, Upper Brookside, September 3, 1931 (869).

*Mycena borealis A. H. Smith (Pl. XXVI, Fig. 1). — This was the most abundant member of the genus during the summer of 1931. It varies greatly in stature, but the characteristic cystidia always enable one to identify it. For a description of the species see A. H. Smith, *Mycologia*, 1935.

*Mycena clavicularis Fr. — On humus, under conifers, Upper Brookside, July 18, 1931 (656); Upper Brookside, August 19, 1931 (656a). The spores of the collections cited above measure 7–8 × 4–5 μ, and the clavate-echinulate cystidia were found scattered on the sides and were numerous on the edges of the lamellae. The colors varied from "Quaker drab" to "Chaetura black" when young, fading to gray or "cinnamon-drab" in age. The colors and the stature of this species vary a great deal; see Peck (14).

*Mycena cyaneobasis Pk. — Scattered, on hardwood débris, Folleigh Lake, August 29, 1931 (840).

Mycena delectabilis Pk. — On needles and humus under spruce, Upper Brookside, August 19, 1931 (793). The following description is taken from the specimens in the collection: Pileus 8–20 mm. broad, conic-campanulate when young, later expanding to conic or plane, often papillate when quite expanded but usually obtuse, striate to disk, often with a faint yellowish tint in age, usually pure white, glabrous; lamellae arcuate-decurrent from the first (like those of *M. immaculata*), subdistant to distant, narrow, white, edge even; stipe 4 cm. × 1–2 mm., tubular, glabrous or slightly pruinose at apex, white, rather transparent, base rooting among needles; cystidia present on sides and edges of lamellae, 25–40 × 5–12 μ, fusoid-ventricose but becoming nearly cylindric at maturity; spores 5–6 × 3 μ, narrowly ellipsoid or acuminate-pointed at the apex; odor strongly alkaline; taste disagreeable.

This is a fragile, white or pale yellowish fungus found in large numbers on needle beds under spruce and fir. Its favorite location for fruiting seems to be in shallow depressions partly covered by fallen débris. The strong odor, color, cystidia, and spores make this a well-marked species.

*Mycena epipterygia Fr. — Scattered, on hemlock logs, Upper Brookside, July 13, 1931 (615); Mt. Thom, August 15, 1931 (757). This is a characteristic plant of coniferous regions. It has no pronounced odor, and the flesh does not stain reddish when bruised. The basidia have been found to bear either two or four sterigmata, although the two-spored condition seems to be more common in the form found on hemlock débris.

*Mycena haematopoda Fr. — Gregarious or cespitose, on wood of various deciduous trees, Mt. Thom, August 10, 1931 (726); Upper Brookside, August 12, 1931 (726a); Earltown Road, August 26, 1931 (826); Folleigh Lake, August 29, 1931 (726d); Upper Brookside, September 5, 1931 (726f); Salmon River, September 8, 1931 (726g). The color of the edges of the lamellae varied considerably in different collections, being concolorous, brownish, or dark reddish brown. The cystidia were found to be abundant on the sides and edges of the lamellae in some collections, rare in others, and apparently present only on the edges in still others. The coloring on the gill edge was caused by colored sap in the cystidia, the abundance of the cystidia thus determining to some extent, at least, the coloring of the gill edge. The spores of the collections were 7.5–10 × 6 μ; 10–11 × 6.5–7 μ; 8–10 × 5–6 μ; 7–7.5 (8) × 4.5–5 μ; 8–11 × 7–7.5 μ, respectively. However, no correlation was found to exist between large or small spores, colored gill margin, size of fruit body, or distribution of cystidia.

*Mycena iodiolens Lundell. — Scattered, on moss under fir and spruce, Upper Brookside, August 24, 1931 (816).

Mycena latifolia Pk. (Pl. XXVI, Fig. 2). — Abundant, under spruce and fir after heavy rains, Upper Brookside, July 16, 1931 (645); Upper Brookside, September 4, 1931 (643a); Upper Brookside, August 14, 1931 (755); Upper Brookside, August 17, 1931 (755a). The following is a description of the collections: Pileus 8–20 mm. broad, obtusely umbonate or convex, becoming plane, "blackish mouse gray" when young or "olivaceous black 3," fading to whitish near the margin in age, "olive-gray" on the disk or pale cinereous over all, pellucid-striate before fading, at times somewhat sulcate after fading, lubricous or subviscid when moist, margin often wavy; flesh thin but tough; lamellae white or grayish, subdistant, quite broad, broadly adnate, edge

concolorous; stipe 2–5 cm. × 1–1.5 (2) mm. (often 6 cm. or more when growing in deep moss), glabrous, grayish, base white-strigose, lubricous when wet; spores 7–8 × 3.5–4 μ, narrowly ellipsoid; basidia four-spored, 18–22 × 5–6 μ; cystidia very abundant on the sides of the gills, 45–60 × 8–12 μ, fusoid-ventricose, apex rather cylindric and obtuse and smooth, ventricose portion smooth or roughened; sterile cells clavate to fusoid-ventricose, the enlarged portion roughened by the presence of short rodlike processes or tubercles. The clavate sterile cells are roughened at the apex, but it seems that quite often the apex elongates, and the newly elongated portion remains smooth. The presence of both types of sterile organs in this species presents an unusual situation but one which is constant for the species.

The rigid cartilaginous consistency of this species is very striking. It resembles *M. vulgaris* and dark forms of *M. clavicularis* somewhat in color, but is easily distinguished by the dry-to-lubricous pileus and stipe. It in no way reminds one of *M. galericulata.*

MYCENA LEAIANA Berk. — Cespitose, on beech, Upper Brookside, July 4, 1931 (568), Folleigh Lake, August 29, 1931 (568). Rather common.

*MYCENA LEPTOCEPHALA Fr. — Singly, under conifers, Upper Brookside, September 4, 1931 (876).

*MYCENA NIGRICANS Bres. — Gregarious, on bare soil under conifers, Upper Brookside, July 2, 1931 (551). The fruit bodies of this collection were very distinct and clearly belong here; however, in view of the fact that there are several very closely related species, and that this species has not been previously recognized with certainty in North America, a complete description is given: Pileus 5–10 mm. broad, convex or slightly umbonate, and composed of two distinct layers, the first of enlarged vesicular cells filled with a dark brown substance, the second a paler one composing the fleshy part of the pileus and made up of filamentous cells (some colored matter could be found in these, but definite light and dark layers can be made out under a hand lens), surface of pileus glabrous, "Chaetura black" on disk, margin "Chaetura drab," often with a canescent appearance but not pruinose, faintly striate; lamellae subdistant, very narrowly adnate, broad, ventricose, concolorous with cap or cinereous, margin usually

paler; stipe 2–4 cm. × 1 mm., white-myceloid at base, otherwise concolorous with pileus, apex becoming paler in age, base extending some distance into the soil; spores 8–10 × 5–6 μ, smooth; basidia four-spored; sterile cells 30–40 × 10–12 μ, fusoid-ventricose, scattered on the edge; odor none.

MYCENA PELIANTHINA Fr. — Singly, under maple and beech, Mt. Thom, August 10, 1931 (730). Found frequently but never in great abundance.

MYCENA PURA Fr. — Under spruce, scattered, Upper Brookside, July 4, 1931 (561), coll. L. E. W.; Upper Brookside, August 27, 1931 (661a). Rather frequent but scattered.

*MYCENA QUINIAULTENSIS A. H. Smith. — The collection from Nova Scotia (Upper Brookside, September 3, 1931 (864)) was found on needles under fir near a small stream. It is interesting to note that this species was discovered on the west coast, but that the first additional collection has been made from a similar habitat in this region.

*MYCENA RORIDA Fr. *sensu* Ricken. — Scattered over large areas and very abundant after drenching rains, under spruce and fir, Upper Brookside, July 16, 1931 (642); Upper Brookside, August 19, 1931 (516a). A striking little fungus of coniferous regions. The ample gelatinous sheath on the stipe, pale color, spores, and sterile cells make it distinct. Since it appears most commonly during periods of wet weather and quickly disappears, one is not apt to collect it.

MYCENA ROSELLA Fr. — On needles under spruce and fir, often in large numbers, Upper Brookside, August 19, 1931 (694).

*MYCENA RUBROMARGINATA Fr. var. LARICIS A. H. Smith. — Scattered, one or two specimens together, on small sticks of fir, Salmon River, July 15, 1931 (635); Salmon River, July 23 (690); Upper Brookside, August 18, 1931 (690a). Both two- and four-spored forms were found.

*MYCENA SANGUINOLENTA Fr. — Scattered, on mossy hummocks and in sphagnum bogs, Upper Brookside, June 27, 1931 (505).

*MYCENA STYLOBATES Fr. *sensu* Ricken. — On fallen leaves of deciduous trees, Upper Brookside, July 23, 1931 (691).

*MYCENA URANIA Fr. — Gregarious, under spruce and fir, Upper Brookside, June 29, 1931 (518); Upper Brookside, July 16, 1931 (518a); Upper Brookside, July 16, 1931 (518b).

*Mycena vulgaris Fr. — Among needles under spruce on a wet hillside, Earltown Road, August 18, 1931 (534).

*Naucoria firma Pk. (Pl. XXVII). — On buried sticks of birch, Earltown Road, August 18, 1931 (785). This species seems to be rather frequent in the northeastern part of North America. Pileus 1–5 (7) cm. broad, convex or obtusely umbonate when young, expanding to plane or remaining slightly umbonate, glabrous, lubricous but not viscid, pellicle not separable, surface rugose-wrinkled when young, smooth or with oval to circular depressions in age, depressions most numerous near the margin, colors fuscous to "fuscous black" when young, margin incurved and with a hoary sheen, in age the entire pileus becoming "hair brown" or fading to "clay color," margin striatulate in age; lamellae "avellaneous," close, thin-adnexed or decurrent by a tooth, narrow (5 mm.), tapering evenly to the margin, edge even; stipe 4–8 cm. × 5–9 mm., compressed in large plants, concolorous with the lamellae, or paler below, with a grayish pruinosity at apex, approaching a scaly condition near the base, flesh pale brown, base white-myceloid, rhizoids numerous; spores "bister" or "snuff-brown" in mass, 7–9 (10) × 4–5 μ, ellipsoid; cystidia scattered on the sides, numerous on the edges of the gills, 35–40 × 15–18 μ, ventricose with a short obtuse neck.

*Nolanea coelestina Fr. — Scattered, on bare soil under beech, Upper Brookside, July 17, 1931 (647). Pileus 5–10 mm. broad, convex when young, broadly conical in age, with a flaring margin, not papillate, "Roslyn blue" to "Bradley's blue," fibrous, apex nearly squarrose-scaly, rimose in age, not hygrophanous, delicately striate from the fibers; flesh white; lamellae broad, adnate, close to subdistant, white, edge concolorous; stipe "dark bluish violet," finely fibrous with paler markings, not scurfy or pruinose, tubular; spores 9–10 (11–12 with apiculus) × 6.5–7.5 μ, angular; no sterile cells or cystidia.

The illustration in Fries' *Icones*, Plate 100, Figure 2, shows a plant slightly larger than ours, but with the same stature. The white flesh is in striking contrast to the bright surface colors. Although found on soil instead of rotten wood, our collection resembles the Friesian conception too closely to allow a separation.

*Nolanea dysthales (Pk.) Atk. — Singly, on humus, Earltown Road, August 21, 1931 (806).

*Nolanea mammosa Fr. — On humus under hardwoods, Earltown Road, August 22, 1931 (811).

*Nyctalis asterophora Fr. — On an old fruit body of a species of Russula, probably *R. nigricans*, Upper Brookside, July 24, 1931 (700).

*Nyctalis parasitica Fr. — On the decaying remains of a species of Russula, Mt. Thom, August 10, 1931 (727), coll. L. E. W.; Mt. Thom, August 30, 1931 (727a). Overholts (13) has found this species in Pennsylvania, growing on the remains of a species of Russula which blackens as it decays. It has also been reported from New York. The host fruit bodies in both of our collections from Mt. Thom were so badly decayed that only a blackened mass was left.

Omphalia campanella Fr. — On conifer stumps, Salmon River, July 3, 1931 (555).

*Omphalia chrysophylla Fr. — On coniferous logs, Folleigh Lake, July 20, 1931 (677). The pilei measured 3–3.5 cm. broad, were "ochraceous tawny" with a pellucid striate margin, and were slightly fibrillose toward the center. The lamellae were "buff yellow" and subdistant. The spores measure 9–10.5 × 5–6 μ.

*Omphalia epichysium Fr. — On beech logs, Mt. Thom, August 10, 1931 (729); Upper Brookside, August 18, 1931 (729a); Princeport, July 9, 1931 (600). Usually solitary or only a few fruit bodies on a log.

Omphalia fibula Fr. — On moss, Upper Brookside, July 4, 1931 (567).

Omphalia Gerardiana Pk. — On sphagnum, New Glasgow Road, June 30, 1931 (533). Murrill (11) lists this species as a synonym for *Omphalina epichysium*, but both are kept separate here. Both were collected and, though there is a slight resemblance, the differences which Kauffman (5) has pointed out were found to be constant.

*Omphalia onisca Fr. — On a sandy bank among mosses, Salmon River, July 3, 1931. This collection agreed well with the description by Kauffman (5) except that the spores measure 7–8 × 4 μ and that the basidia are two-spored. Ricken (17) describes the spores as pear-shaped and 7–8 × 4 μ.

*Omphalia rugosodisca Pk. — On fir stumps and logs, Folleigh Lake, July 20, 1931 (686). Very common and usually found in considerable abundance.

*Omphalia Schwartzii Fr. — Singly, on moss, Upper Brookside, July 4, 1931 (566).

Panaeolus campanulatus Fr. — On cow dung, Upper Brookside, June 27, 1931 (509); Upper Brookside, July 1, 1931 (509a).

Panus stipticus Fr. — On birch, Upper Brookside, July 1, 1931 (539).

Paxillus involutus Fr. — On mossy hummocks, on humus in fir woods, and on decaying beech logs, Salmon River, July 15, 1931 (629); Upper Brookside, August 17, 1931 (629a); July 28, 1931 (711).

*Pholiota acericola Pk. — On decaying beech trunks, Upper Brookside, July 10, 1931 (602); Upper Brookside, July 18, 1931 (602a).

*Pholiota albocrenulata Pk. — On a fallen birch trunk, Mt. Thom, August 15, 1931 (726).

Pholiota caperata Fr. — On humus, Upper Brookside, July 13, 1931 (655); Upper Brookside, July 18, 1931 (655a). This species was found on comparatively dry slopes under maple and also in swampy areas or bogs.

*Pholiota confragosa Fr. — On an old log, probably maple or beech, Upper Brookside, August 20, 1931 (799).

*Pholiota erebia Fr. — On old logs and débris, sometimes appearing to be terrestrial, Earltown Road, August 21, 1931 (805).

*Pholiota flammans Fr. — On very decayed wood in a mixed forest of beech, hemlock, and spruce, Upper Brookside, September 2, 1931 (857).

*Pholiota mutabilis Fr. — On a birch log, Earltown Road, August 18, 1931 (783).

*Pholiota spectabilis Fr. — On frondose wood, Upper Brookside, August 12, 1931 (738), coll. L. E. W.

Pholiota squarrosoides Pk. — On beech, Upper Brookside, September 3, 1931 (862).

*Pholiota trachyspora Cl. & Cl. — On mossy soil under fir and hemlock, Salmon River, July 3, 1931. Pileus 4–7 cm. broad, broadly campanulate with a sharp and pronounced umbo, "auburn" to "Brussels brown," covered by matted fibrils or

scaly, scales more pronounced near the apex, appressed-fibrillose at the margin; lamellae adnate, becoming adnexed, "Mars brown" when old, 4–8 mm. broad, not ventricose, broadest at the base and tapering evenly; stipe concolorous, 8–12 cm. × 6–10 mm., covered by loose fibrils, not truly hollow, annulus superior and very persistent; spores 7–8 × 5 μ, very dark brown and rough-walled; no sterile cells or cystidia seen; odor none, taste resembling that of a radish.

Overholts (12) reports this species as known only from the type locality in Colorado, and describes the pileus as convex. The specimens collected differed strikingly in this one respect, having decidedly conical pilei. Professor Overholts, to whom a portion of the collection was submitted, agrees that until more is known of the variations of the species, it would seem best not to regard the conical form as distinct. The terrestrial habitat, colors, and rough-walled spores clearly indicate its relationship.

*Pholiota vermiflua Pk. — In an open field, Upper Brookside, August 18, 1931 (772).

Phylloporus rhodoxanthus (Schw.) Bres. — Singly, in mixed deciduous and coniferous woods, Upper Brookside, July 14, 1931 (626), coll. L. E. W.

*Pleurotus atrocaeruleus Fr. var. griseus Pk. — On hardwood débris and rotting logs, Upper Brookside, June 29, 1931 (521); on fir, Victoria Park, Truro, August 30, 1933 (1646), coll. L. E. W. The spores measure 7 9 × 4 μ, but otherwise the fruit bodies were typical. The gelatinous layer was very striking.

*Pleurotus candidissimus B. & C. — On wood of a deciduous tree, Upper Brookside, July 11, 1931 (605).

Pleurotus ostreatus Fr. — On an aspen stub, Upper Brookside, July 12, 1931 (609), coll. L. E. W.

*Pleurotus sapidus Kalch. — On birch, Upper Brookside, July 1, 1933, coll. L. E. W.

*Pleurotus tremulus Fr. — On Dicranum, New Glasgow Road, June 30, 1931 (536). A brownish gray species of rather watery consistency. The lamellae are subdistant and often forked. Hesler (4) has reported this species from Tennessee and gives a good description.

*Pluteus admirabilis Pk. — On a decaying log, Folleigh Lake, July 20, 1931 (679).

PLUTEUS CERVINUS Fr. — On hardwood débris, Upper Brookside, July 24, 1929 (88), coll. L. E. W.; Upper Brookside, June 29, 1931 (525), coll. L. E. W. Common throughout the summer, but never in large numbers.

*PLUTEUS LONGISTRIATUS Pk. — On a rotten stump, Upper Brookside, July 8, 1931 (590).

*PLUTEUS TOMENTOSULUS Pk. — Singly, on humus in a spruce swamp, Upper Brookside, August 14, 1931 (750).

*PLUTEUS UMBROSUS Fr. — Singly, on decaying coniferous wood, Upper Brookside, August 26, 1931 (833).

*PSALLIOTA ABRUPTIBULBA Pk. — Under maple and beech, Upper Brookside, July 16, 1931 (638); Mt. Thom, August 15, 1931 (638a).

PSALLIOTA CAMPESTRIS Fr. — In pastures, Upper Brookside, August 14, 1931 (749); Onslow, August 28, 1933, coll. L. E. W. A pure white form, as well as a form with a grayish to brownish pileus, was collected. In the latter the fibrillose scales were pinkish to violet-brown.

*PSALLIOTA DIMINUTIVA Pk. — Scattered, on humus in mixed woods, Upper Brookside, July 21, 1931 (648); Mt. Thom, August 10, 1931 (725).

*PSALLIOTA SUBRUFESCENS Pk. — Under beech and maple, Upper Brookside, August 12, 1931 (731).

*RUSSULA ABIETINA Pk. — Under fir and spruce, Upper Brookside, July 4, 1931 (572).

*RUSSULA AERUGINEA Lindbl. — On bare soil, Upper Brookside, 1930 (113), coll. L. E. W.; Upper Brookside, 1931 (741), coll. L. E. W.

*RUSSULA ALBIDA Pk. — In mixed woods, Upper Brookside, July 22, 1929 (118), coll. L. E. W.; Victoria Park, Truro, 1930 (232), coll. L. E. W.; Victoria Park, Truro, July 8, 1931 (587).

RUSSULA ALUTACEA Fr. — Scattered, under larch in a swampy flat, Upper Brookside, July 8, 1931 (586); Victoria Park, Truro, July 22, 1931 (586a).

*RUSSULA BASIFURCATA Pk. — Singly, on humus in a mixed forest, Upper Brookside, July 10, 1931 (601).

*RUSSULA BOREALIS Kauff. — On humus under conifers, Upper Brookside, August 12, 1931 (740).

*RUSSULA BRUNNEOLA Burl. — Under spruce, Salmon River, July 14, 1931 (624).

*Russula chamaeleontina Fr. — Under fir, Upper Brookside, July 8, 1931 (585).

*Russula cyanoxantha Fr. — On humus in mixed woods, Upper Brookside, July 18, 1931 (658). These plants did not have scattered short gills, but were typical otherwise.

*Russula decolorans Fr. — Singly, in mixed woods, Upper Brookside, August 19, 1931 (796).

*Russula delica Fr. — On humus, Upper Brookside, July 6, 1931 (576).

*Russula densifolia Secr. — On humus in mixed woods, Salmon River, July 14, 1931 (622); Upper Brookside, July 28, 1931 (622a). This species is one of the most common found during the summer. It occurs in troops under spruce. The change to red and finally black which the flesh undergoes when bruised was conspicuous. The close gills separate it from *R. nigricans.*

Russula emetica Fr. — Gregarious, on sphagnum in bogs, Upper Brookside, June 30, 1931 (535). A common species throughout the summer and fall.

*Russula fallax Cke. — On humus under hemlock, Upper Brookside, July 18, 1931 (654).

*Russula flava Romell. — In mixed woods, Upper Brookside, July 11, 1931 (608); Salmon River, August 13, 1931 (608a).

Russula foetens Fr. — Gregarious, under conifers, Victoria Park, Truro, August 8, 1929 (230), coll. L. E. W.; Upper Brookside, July 14, 1931 (620). The most common Russula during the summer.

*Russula fragilis Fr. — On conifer duff, Upper Brookside, 1930 (123), coll. L. E. W.; Upper Brookside, June 30, 1931 (526); Upper Brookside, July 14, 1931 (526a).

Russula integra Fr. — On the ground in fir woods, Upper Brookside, July 1, 1931 (546); Upper Brookside, July, 1931 (625a).

*Russula Mariae Pk. — On humus, July 21, 1929 (162), coll. L. E. W.

*Russula nigricans Fr. — Singly, in mixed woods, Cape Breton Island, August 4, 1931 (722); Mt. Thom, August 15, 1931 (722a). These two collections differed from *R. densifolia* in having truly distant gills and a slightly different stature.

*Russula ochraleucoides Kauff. — On humus under hardwoods, Upper Brookside, September 9, 1931 (860). Pileus 6 9.5 cm. broad, broadly convex or with a shallow depression, very firm,

fleshy, margin decurved, obtuse, and faintly striate, pellicle not or scarcely separable, surface velvety from more or less upright hyphae which are filled with a yellowish content, colors "yellow-ocher" near the margin, disk "ochraceous tawny" to "ochraceous orange," flesh yellow-ocher beneath the surface layer, then white, not becoming ashy where bruised; gills close, usually forked at the base, narrowly adnate to nearly free, broader anteriorly, about 1 cm. broad in widest part, white with a yellow-ocher edge; stipe 4–5 × 1–2 cm. with yellow or ochraceous patches giving it an appearance in places much like that of the pileus but paler, white-pulverulent otherwise, solid, stuffed; spores white in mass, globose, 7–8.5 μ, echinulate; cystidia present on sides and edge of gills, filled with a granular content. The fruit bodies in this collection seem to be too closely related to *R. ochroleucoides* to justify being separated from it. In the latter, however, the gills are not bordered, and the stipe is white.

*Russula rugulosa Pk. — Under hemlocks, Upper Brookside, July 8, 1931 (588).

*Russula sericionitens Kauff. — Under hardwoods, Upper Brookside, July 9, 1931 (594).

*Russula sordida Pk. — Under hemlock, Upper Brookside, July 18, 1931 (663).

*Russula sphagnophila Kauff. — On moist hillside under spruce, Upper Brookside, July 4, 1931 (571).

*Russula squalida Pk. — In mixed woods, Upper Brookside, 1930 (85), coll. L. E. W.; Upper Brookside, July 4, 1931 (537).

*Russula subdepallens Pk. — Singly, in hardwoods, Killag Mines, Halifax County, July 30, 1931 (717).

*Russula subsordida Pk. — Under fir and spruce, Upper Brookside, July 1, 1931 (541).

*Russula tenuiceps Kauff. — Under hardwoods, Upper Brookside, July 27, 1931 (707).

Russula variata Bann. — Singly, in mixed woods, Upper Brookside, July 28, 1931 (710); Upper Brookside, August 12, 1931 (710a).

*Russula virescens Fr. — Under spruce and beech, Upper Brookside, July 28, 1931 (709).

*Russula xerampelina Fr. — Mixed woods, Salmon River, July 14, 1931 (623).

Schizophyllum commune Fr. — Common on old wood, Westcooke Cove, Guysboro County, 1933 (1121), coll. L. E. W.

Stropharia semiglobata Fr. — On cow dung, Upper Brookside, June 29, 1931 (523).

*Tricholoma impolitum Lasch. — In mixed forests of spruce and beech, Salmon River, September 7, 1931 (894). This species is characterized by the pale creamy colors, the flesh, which changes to a bright sulphur-yellow when cut or bruised, and by the acrid-bitter taste.

*Tricholoma naucoria Murr. — Under fir and spruce, Upper Brookside, July 14, 1931 (627).

*Tricholoma resplendens Fr. — In mixed deciduous and conifer woods, Upper Brookside, September 2, 1931 (858).

*Tricholoma rutilans Fr. — On fir wood, Upper Brookside, July 4, 1931 (564).

*Tricholoma saponaceum Fr. — Scattered, under spruce, Upper Brookside, July 11, 1931 (607). This was a very common species throughout the summer, appearing after periods of rainy weather from July 8 to September. The pileus is "light yellowish olive" to "yellowish olive," subhygrophanous in wet weather, and rather firm and fleshy.

*Tricholoma terreum Fr. — Under spruce and fir, Upper Brookside, September 4, 1931 (880).

*Tricholoma vaccinum Fr. — Under conifers, Upper Brookside, September 4, 1931 (878).

*Tricholoma virgatum Fr. — Under conifers, Upper Brookside, September 4, 1931 (879).

Trogia crispa Fr. — On beech, Killag Mines, Halifax County, July 30, 1931, coll. L. E. W.

BOLETACEAE

Boletinus paluster Pk. — Under fir, Upper Brookside, July 28, 1931 (712).

Boletinus pictus Pk. — Under fir, Upper Brookside, July 28, 1931 (694).

Boletus americanus Pk. — On the ground under Alnus and other shrubs, Victoria Park, Truro, July 22, 1931 (687).

Boletus badius Fr. — Gregarious, on humus in beech woods, Folleigh Lake, July 20, 1931 (672); Upper Brookside, July 22,

1931 (672a). The flesh is blue next to the tubes, the pileus viscid, and the stipe covered by a brown pruinosity.

Boletus castaneus Fr. — Gregarious, on humus in a mixed forest, Folleigh Lake, July 29, 1931 (671).

Boletus chromapes Frost. — Scattered, on grassy soil under spruce, Upper Brookside, July 1, 1931 (538). Never abundant, but found occasionally throughout the summer.

Boletus cyanescens Fr. — Gregarious, on a bare hillside, under maple, Upper Brookside, August 11, 1931 (734), coll. L. E. W.; Upper Brookside, August 12, 1931 (734a).

Boletus edulis Fr. — Under conifers on needle beds and in grassy places, Upper Brookside, June 29, 1931 (519). This was the most common species of the genus throughout the summer, reappearing after periods of rainy weather. It is usually found growing singly, or several in a small area.

Boletus elegans Fr. — Gregarious, under spruce at the base of a steep slope, Upper Brookside, August 31, 1931 (847).

Boletus eximius Pk. — Closely gregarious, under spruce and fir in grassy places, Upper Brookside, July 6, 1931 (574).

Boletus felleus Fr. — On very rotten wood, two or three specimens in a single locality, Salmon River, July 14, 1931 (626); Upper Brookside, July 24, 1931 (626a); Mt. Thom, August 10, 1931 (626b), coll. L. E. W.

*Boletus firmus Frost. — Gregarious, on bare soil under beech, Upper Brookside, July 13, 1931 (610), coll. L. E. W.; Upper Brookside, July 17, 1931 (610a).

Boletus granulatus Fr. — Gregarious, under conifers, Salmon River, July 14, 1931 (622).

Boletus hemichrysus B. & C. — On an old stump, Folleigh Lake, August 29, 1931 (870), coll. L. E. W.

Boletus luridus Fr. — Singly under conifers, Upper Brookside, July 1, 1931 (544), coll. L. E. W. Never found in large numbers, but seen frequently throughout the summer.

Boletus pachypus Fr. — Growing in a wide arc in a hayfield bordered by spruce, Upper Brookside, July 20, 1931 (670). Pileus 12–26 cm. broad, stipe 8–10 × 3–5 cm. The pileus was alutaceous on the disk and reddish toward the margin; the stipe was yellow at the apex when young but reddish over all at maturity.

Boletus Peckii Frost. — On the ground in an open wood, Upper Brookside, July 24, 1931 (696).

Boletus piperatus Fr. — Scattered, on soil under conifers, Upper Brookside, July 8, 1931 (584).

Boletus rubinellus Pk. — Scattered in mixed woods, Salmon River, August 4, 1931 (621).

Boletus scaber Fr. var. mutabilis Pk. — Under spruce on a dry hillside, Upper Brookside, June 28, 1931 (513). The flesh turned brownish where bruised.

Boletus scaber Fr. var. niveus Pk. — On humus in mixed woods, Upper Brookside, July 24, 1931 (695).

Boletus subaureus Pk. — Scattered, in open woods under hemlock and beech, Victoria Park, Truro, July 6, 1931 (573); Upper Brookside, July 27, 1931 (573a); August 31, 1931 (573b).

Boletus subtomentosus Fr. — Singly, on bare soil, Upper Brookside, July 2, 1931 (550), coll. L. E. W.

Boletus versipellis Fr. — In clusters or arcs under spruce, Upper Brookside, July 3, 1931 (552). A very large species, common during the last of June and early July, but observed throughout the summer and early fall.

Boletus viscidus Fr. — Singly, under spruce and fir, Upper Brookside, July 8, 1931 (591).

Strobilomyces strobilaceus Berk. — Singly, under hardwoods, Mt. Thom, August 10, 1931 (724).

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LITERATURE CITED

1. Burt, E. A. 1914. The Thelephoraceae of North America. II. Craterellus. Ann. Mo. Bot. Gard., 1 : 327–350.

2. Farlow, W. G., and Burt, E. A. 1929. Icones Farlowianae. Cambridge, Mass.

3. Heim, R. 1931. Le Genre Inocybe, précédé d'une introduction générale à l'étude des agarics ochrosporés. Encyclopédie mycologique, 1 : 1–431.

4. Hesler, L. R. 1933. *Pleurotus tremulus* Fr. and *Secotium conicum*, n. sp. Journ. Elisha Mitchell Sci. Soc., 49 : 151–155.

5. Kauffman, C. H. 1918. The Agaricaceae of Michigan. Lansing, Michigan.

6. —— 1923. The Genus Armillaria in the United States and Its Relationships. Pap. Mich. Acad. Sci., Arts and Letters, 2 (1922) : 53–66.

7. Kauffman, C. H. 1932. Cortinarius. North American Flora, 10 : 282–348.

8. Konrad, P. 1925. Notes critiques sur quelques champignons du Jura. Deuxième Série. Bull. Soc. Myc. France, 41 : 33–70.

9. MacKay, A. H. 1907. Fungi of Nova Scotia; a Provisional List. Proc. and Trans. Nova Scotian Inst. Nat. Sci., 11 (1902–3) : 122–143.

10. —— 1908. Fungi of Nova Scotia; First Supplementary List. *Ibid.*, 12 (1906–7) : 119–138.

11. Murrill, W. A. 1916. Omphalina. North American Flora, 9, Part 5.

12. Overholts, L. O. 1927. A Monograph of the Genus Pholiota in the United States. Ann. Mo. Bot. Gard., 14 : 87–210.

13. —— 1933. Mycological Notes for 1930–32. Mycologia, 25 : 418–430.

14. Peck, C. H. 1885. Rep. New York State Mus., 38 : 109.

15. —— 1901. New York State Mus. Bull., 54 : 950.

16. Rea, Carleton. 1922. British Basidiomycetae. Cambridge, England.

17. Ricken, A. 1915. Die Blätterpilze Deutschlands. Leipzig.

18. Snell, W. H. 1933. Notes on Boletes II. Mycologia, 25 : 221–232.

19. Wehmeyer, L. E. 1935. Contributions to a Study of the Fungous Flora of Nova Scotia. I. Pap. Mich. Acad. Sci., Arts and Letters 20 (1934) : 233–266.

PLATES XXVI–XXVII

PLATE XXVI

FIG. 1. *Mycena borealis* A. H. Smith, × 1

FIG. 2. *Mycena latifolia* Pk., × 1

PLATE XXVII

Naucoria firma Pk., × 1

NOTES ON ALGAE FROM THE TROPICAL ATLANTIC OCEAN. III *

WM. RANDOLPH TAYLOR

ON TWO previous occasions the writer (1929, 1933) presented lists of algae from various sources in the tropical Americas, representing small collections which had come to his hands for study. In view of the need of a comprehensive catalog of the marine flora of the whole area, the advantages of periodic publication of accumulated records are obvious. The present paper is largely based on material acquired by the University of Michigan, with a few items from the writer's own herbarium.

The collections from Colombia are rather small to give a clear idea of the local flora, but it seems to be in accord with the general character of the coast. There is required only a word of explanation but no apology for the introduction under this general title of records from the Gulf Coast of the United States. We know almost nothing of the flora of the northern rim of the Gulf of Mexico. What we find published earlier and the new records here incorporated of the northwestern and the northeastern Gulf shores of Texas and Florida show that there the vegetation is still predominantly tropical, as it is on the Florida east coast (1928, 1929). Though it is probable that the northern rim will prove to have a flora reduced in the conspicuous tropical elements, it is likely that it will have more tropical than cold-temperate affinities.

To the collectors of these groups of specimens the writer is indebted for data on the environments in which they occurred, as well as for the specimens themselves. Acknowledgment is accorded in the sections of the paper.

Marine Algae from Colombia

Exceedingly few records of algae from Colombia exist. During a visit paid to the vicinity of Santa Marta in early July, 1932,

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 524.

Dr. Thomas Kerr incidentally secured for the writer several marine algae and some vials of alpine fresh-water algae from the inland mountains. The latter group of specimens proved most interesting, particularly the desmids, and publication of a report on them elsewhere is pending. The collections of marine algae were made from two to five miles south of the town of Santa Marta, which lies at approximately 10° 15′ N. L. Here there is a beach broken by rocky spurs which extend down from the hills behind the shore. On one of them remain the ruins of the sixteenth-century Castillo de San Fernando. The land vegetation behind the beach is xerophytic, characterized by cacti and low-lying leguminous shrubs. The tidal range on this coast is reported to have the slight amplitude of 18 inches. The algae collected were all obtained from the littoral rocks, and the collector reports an apparently scanty flora at the time of his visit.

CHLOROPHYCEAE

Ulva fasciata Delile.
Ulva Lactuca L.
Chaetomorpha media (C. Ag.) Kütz.
Cladophora fascicularis (Mert.) Kütz.
Caulerpa sertularioides (Gmel.) Howe.

PHAEOPHYCEAE

Dictyota cervicornis Kütz.
Padina Vickersiae Hoyt.

RHODOPHYCEAE

Hypnea musciformis (Wulf.) Lamx.
Acanthophora spicifera (Vahl) Børg.
Laurencia obtusa (Huds.) Lamx.
Spyridia filamentosa (Wulf.) Harv.
Wrangelia Argus Mont.
Grateloupia filicina (Wulf.) J. Ag.

While studying certain collections of West Indian marine algae at the British Museum of Natural History through the kindness of the keeper of botany, Mr. J. R. Ramsbottom, and the assistant keeper in charge of the algae, Mr. Geoffrey Tandy, the writer noticed

two specimens from New Grenada, now Colombia, collected in 1842–43 by I. Linden. They were, respectively, number 1523, *Caulerpa cupressoides* (West) C. Ag., near var. *Turneri* Weber-van Bosse, and number 1522, *Caulerpa sertularioides* (Gmel.) Howe. The first is an addition to the list as given above.

Marine Algae from Texas

Except for perhaps four or five scattered records of marine algae, we have until recently known nothing of the seaweeds of the Texan shores. In 1931 there appeared in a house organ issued by a biological supply company a list of marine algae, the identification of which was attributed to Dr. M. A. Howe ("O. S.," 1931). Since this publication is not widely available among botanists outside the United States, it seems worth while to summarize the information contained. From the jetties of Mustang Island near Port Aransas, Nueces County (approximately 27° 30′ N. L.), there were collected in April, 1930: *Enteromorpha lingulata* J. Ag., *Ulva Lactuca* L., *Cladophora fascicularis* (Mert.) Kütz., *C. variegata* (C. Ag.) Zanard., *Ectocarpus Mitchellae* Harv., *E. Rallsiae* Vickers, *Bangia fuscopurpurea* (Dillw.) Lyngb., *Gelidium corneum* (Huds.) Lamx., *Hypnea musciformis* (Wulf.) Lamx., and *Gracilaria lacinulata* (Vahl.) Howe. From the south jetties of Galveston Island in Galveston County (approximately 29° 20′ N. L.) during 1929-30 there were secured: *Lyngbya aestuarii* (Mert.) Liebm., *Microcoleus chthonoplastes* (Fl. Dan.) Thuret, *Enteromorpha lingulata* J. Ag., *Ulva Lactuca* L., *Ectocarpus siliculosus* (Dillw.) C. Ag., *Sargassum fluitans* Børg., *Bangia fuscopurpurea* (Dillw.) Lyngb., *Gelidium pusillum* (Stackh.) Le Jolis, and *Gracilaria Blodgettii* Harv. The writer has been enabled to examine duplicates of a part of this material through the kindness of Mr. Ottys Sanders.

Two small collections of marine algae from the Texas area have come directly to the writer's hands for study. The first of these was made by E. L. Cheatum late in April, 1930, at Galveston, and was placed at the writer's disposal by C. L. Lundell. It appears to have been collected from jetties.

The second of these collections was obtained by Miss Elzada Clover in early August, 1932, from Boca Chica, Cameron County (approximately 26° N. L.). Boca Chica, which is the first channel that cuts across the south end of Padre Island, separates it from

the small island Brazos Santiago, on which is located a settlement that takes its name from the channel. The island is, therefore, just north of the estuary of the Rio Grande, and hence very close to the southernmost limit of the state. It is low and of alluvial materials, but pilings and the rocks placed for jetties give good stations for the growth of algae. The following have been obtained:

CHLOROPHYCEAE

Enteromorpha lingulata J. Ag. — Boca Chica, August, *Clover*. Galveston, April, *Cheatum*. On boulders of jetties and on logs floating near shore.

Cladophora fascicularis (Mert.) Kütz. — Boca Chica, August, *Clover*. Galveston, April, *Cheatum*. On boulders, pilings, and logs near shore.

Ulva fasciata Delile. — Boca Chica, August, *Clover*. On boulders, pilings, and logs exposed to wave action.

PHAEOPHYCEAE

Ectocarpus confervoides (Roth) Le Jolis. — Galveston, April, *Cheatum*. On jetties.

Ectocarpus Duchassaignianus Grun. — Boca Chica, August, *Clover*. On a huge log near shore.

Sargassum natans (L.) J. Meyen. — Galveston, April, *Cheatum*. Floating.

RHODOPHYCEAE

Gelidium crinale (Turn.) J. Ag. — Boca Chica, August, *Clover*. Galveston, April, *Cheatum*. On boulders exposed to sun and waves, and on jetties.

Agardhiella tenera (J. Ag.) Schmitz. — Boca Chica, August, *Clover*. Near shore.

Hypnea cervicornis J. Ag. — Boca Chica, August, *Clover*. On a huge log near shore.

Hypnea musciformis (Wulf.) Lamx. — Boca Chica, August, *Clover*. On a log near shore.

Gracilaria lacinulata (Vahl) Howe. — Boca Chica, August, *Clover*. Growing near boulders and pilings exposed to the action of waves.

Amphibia Moritziana Mont. — Galveston, April, *Cheatum*. On jetties.

Bryocladia cuspidata (J. Ag.) De Toni. — Boca Chica, August, *Clover*. On a log near shore.

Wrightiella Tumanowiczii (Gatty) Schmitz. — Boca Chica, August, *Clover*. Badly worn, but apparently surely this species.

Centroceras clavulatum (C. Ag.) Mont. — Boca Chica, August, *Clover*.

Marine Algae of West Florida

In discussing a few algae from the Texas coast the writer has mentioned the scarcity of records from the western part of the Gulf Coast. The same situation exists respecting the eastern portion. It is rather curious that the early phycologists should have collected so exclusively on the eastern coast line of Florida. It is probably true that a greater part of the western shore line is unsuitable for a luxuriant algal flora. So far as the writer is aware, the only records of marine algae along the northern portion of the Gulf Coast east of Texas are contained in Mohr's flora of Alabama (Mohr, 1901). They are there recorded as: *Ulva Lactuca* (L.) Le Jolis, *Ulva enteromorpha* Le Jolis, *Sargassum bacciferum* Turn., *S. vulgare* C. Ag., *Gracilaria armigera* Harv., and *Caloglossa Leprieurii* J. Ag.[1] We may assume that these probably represent *Ulva Lactuca* L., *Sargassum natans* (L.) J. Meyen, and *Caloglossa Leprieurii* (Mont.) J. Ag., with the second, fourth, and fifth items uncertain. Through the kindness of Mrs. John Chipman (Dr. Ruth Hayes) there have come to the writer four specimens from Ocean Springs, Jackson County, Mississippi. Two of these were very distinctive species of Polysiphonia, which have so far not been successfully identified. The other two were:

[1] Through the kindness of Mr. W. R. Maxon the writer has had the opportunity to examine four sheets from the collections of Charles Mohr in the National Herbarium. One of these was of *Caloglossa Leprieurii*, from the mouth of the Mobile River; the determination by the Reverend A. B. Hervey is quite correct. The three other sheets were of Sargassa. Only one was annotated as from Alabama; the legend, though abbreviated, is understood to indicate that the material was washed ashore in Mississippi Sound. It has very broad leaves for that species, but is probably *S. natans* (L.) J. Meyen. The other two specimens of Sargassum bear old herbarium labels of Hervey's, without any data; one, determined as *S. bacciferum*, is the ordinary form of *S. natans;* the other, determined as *S. vulgare*, is in rather poor condition for a determination. The leaves seem to lack cryptostomata, or have very few; possibly it is a form of *S. fluitans* Børg., with spiny stems.

Ulva Lactuca L.
Ectocarpus siliculosus (Dillw.) Lyngb.

Florida material has come to the Herbarium of the University of Michigan from three sources. A few specimens were collected by Mrs. Chipman at Carrabelle, Franklin County (approximately 29° 50′ N. L.) in the western extension of the state. A few more were contributed by Professor B. M. Davis at Naples, Collier County (approximately 26° 10′ N. L.); they were collected in March, 1933. The largest group was assembled by James McFarlin while engaged as collector for the University. These came from several stations: Tarpon Springs and off the Anclote River, in Pinellas County (approximately 28° 15′ N. L.), Clearwater in the same county (approximately 27° 55′ N. L.), Tampa a little to the east in Hillsborough County, and Hillsborough Bay, the eastern lobe of Tampa Bay (approximately 27° 55′ N. L.), and Cortez Beach in Manatee County (approximately 27° 30′ N. L.). The vigor of the specimens shows that favorable conditions for growth, though in area somewhat restricted, are such that marine algae of a tropical type develop well on the west coast of Florida at least as far north as the Tampa neighborhood. Though the collections aggregate but a few species, mostly conspicuous ones, the characteristically tropical genera dominate the list.

CHLOROPHYCEAE

Enteromorpha lingulata J. Ag. — Naples, March, *Davis*. Tarpon Springs, June, *McFarlin*. Adrift and on pilings in shallow water.

Monostroma latissimum (Kütz.) Wittr. (?). — Naples, March, *Davis*. On piles of a wharf, in shallow water. The cells are rather small, the walls are thick, and the color is dark for this species.

Ulva fasciata Delile. — Hillsborough Bay, Tampa, May, *McFarlin*. On oyster beds, exposed at low tide.

Ulva Lactuca L. — Hillsborough Bay, Tampa, May, *McFarlin*. On oyster beds, exposed at low tide.

Ulva Lactuca var. latissima (L.) DC. — Hillsborough Bay, Tampa, May, *McFarlin*. Floating over oyster beds.

Chaetomorpha brachygona Harv. — Cortez Beach, July, *McFarlin*. Adrift.

Chaetomorpha gracilis Kütz. — Cortez Beach, July, *McFarlin.* Adrift.

Acetabulum crenulatum (Lamx.) Kuntze. — Tarpon Springs, June, *McFarlin.*

Batophora Oerstedi J. Ag. — Tarpon Springs, June, *McFarlin.* In eight feet of water, on solid objects scattered over a muddy bottom.

Batophora Oerstedi var. occidentalis (Harv.) Howe. — Clearwater, August, *McFarlin.* On shells scattered over a sandy mud flat.

Caulerpa Ashmeadii Harv. — Clearwater, August; Tarpon Springs, June, *McFarlin.* Adrift and rooted in the muddy bottom. This is typical material; the ramuli have their tips unarmed and their bases are uncontracted. With this occurred the animal Zoöbotrys, which at one time appeared in algal lists under the name Ascothamnion.

Caulerpa crassifolia (C. Ag.) J. Ag. — Clearwater Beach, August, *McFarlin.* Drifting inshore.

Caulerpa cupressoides (West) C. Ag. var. flabellata Børg. — Clearwater Beach, August, *McFarlin.* Drifting inshore.

Caulerpa prolifera (Forsk.) Lamx. — Hillsborough Bay, Tampa, May, *McFarlin.* Rooting in the mud in four feet of water.

Halimeda tridens (Ell. & Sol.) Lamx. f. tripartita (Bart.) Collins. — Tarpon Springs, June, *McFarlin.* Rooting in the mud in from six to eight feet of water.

Penicillus capitatus Lamk. — Tarpon Springs, June, *McFarlin.* Rooting in the mud in from six to eight feet of water.

Udotea conglutinata (Sol.) Lamx. — Madeira Beach, August, *McFarlin.* Drifted ashore.

Udotea Flabellum (Ell. & Sol.) Howe. — Madeira Beach, August, *McFarlin.* Drifted ashore.

phaeophyceae

Ectocarpus confervoides (Roth) Le Jolis. — Naples, March, *Davis.* On piles of wharf.

Castagnea Zosterae (Mohr) Thuret. — Carrabelle, summer, *Chipman.*

Dictyota cervicornis Kütz. — Tarpon Springs, June, *McFarlin.* Floating inshore.

Sargassum pteropleuron Grun. — Madeira Beach, July; Tarpon Springs, June, *McFarlin.* Growing in eight feet of water.

RHODOPHYCEAE

Gelidium crinale (Turn.) Lamx. — Hillsborough, May, *McFarlin.* Forming dense tufts on oyster shells; in shallow water, exposed at low tide.

Eucheuma Gelidium J. Ag. — Cortez Beach, July; Clearwater Beach, August; Tarpon Springs, June, *McFarlin.* Drifting, and growing on sponges in fifteen feet of water.

Gracilaria Blodgettii Harv. — Cortez Beach, July, *McFarlin.* Drifting ashore.

Gracilaria confervoides (L.) Grev. — Naples, March, *Davis.* Hillsborough, May, *McFarlin.* Drifting, or in four feet of water on a muddy bottom.

Gracilaria cornea J. Ag. — Clearwater Beach, August, *McFarlin.* Drifted ashore.

Hypnea cervicornis J. Ag. — Naples, March, *Davis.* Drifted ashore.

Champia parvula (C. Ag.) Harv. — Carrabelle, summer, *Chipman.*

Chrysymenia uvaria (L.) J. Ag. — Madeira Beach, August, *McFarlin.* Drifted ashore.

Acanthophora muscoides (L.) Bory. — Naples, March, *Davis.* Drifting inshore.

Acanthophora spicifera (Vahl) Børg. — Clearwater Beach, August, *McFarlin.* Floating inshore.

Chondria tenuissima (Good. & Wood.) C. Ag. — Carrabelle, summer, *Chipman.*

Laurencia intricata Lamx. — Clearwater Beach, August, *McFarlin.* Drifting inshore.

Laurencia Poitei (Lamx.) Howe. — Tarpon Springs, June, *McFarlin.* Attached in eight feet of water.

Polysiphonia ramentacea Harv. — Five miles off the Anclote River, Tarpon Springs, July; Clearwater Beach, August, *McFarlin.* Old and worn drifting material.

Polysiphonia subtilissima Mont. — Naples, March, *Davis.* On piles of a wharf.

Ceramium strictum (Kütz.) Harv. f. — Carrabelle, summer, *Chipman.* Probably a new record for the state.

Centroceras clavulatum Mont. — Hillsborough Bay, Tampa, May, *McFarlin*. Carrabelle, summer, *Chipman*. Entangled in other, larger, algae.

Spyridia filamentosa (Wulf.) Harv. — Naples, March, *Davis*. Clearwater, August; Hillsborough, May, *McFarlin*. Floating, and attached in from four to ten feet of water over a muddy bottom.

Halymenia Floresia (Clem.) J. Ag. — Cortez Beach, July, *McFarlin*. Drifting inshore.

Halymenia gelinaria Collins & Howe. — Cortez Beach, July, *McFarlin*. Drifting inshore. Determined by the kindness of Dr. M. A. Howe.

Melobesia farinosa Lamx. — Carrabelle, summer, *Chipman*. Apparently attached to Thalassia leaves.

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LITERATURE CITED

Mohr, Charles T. 1901. Plant Life of Alabama. Contrib. United States Nat. Herb., 6 : 1–921.

"O. S." 1931. Texas Marine Algae. Bio-Log (The Southwestern Biological Supply Company, Dallas, Texas), 1 : 26.

Taylor, Wm. Randolph. 1928. The Marine Algae of Florida, with Special Reference to the Dry Tortugas. Papers from the Tortugas Laboratory, 25 : 1–219. Publ. 379, Carnegie Institution, Washington.

—— 1929. Notes on the Marine Algae of Florida. Bull. Torr. Bot. Club, 56 : 199–210.

—— 1929. Notes on Algae from the Tropical Atlantic Ocean. Am. Journ. Bot., 16 : 621–630.

—— 1933. Notes on Algae from the Tropical Atlantic Ocean. II. Pap. Mich. Acad. Sci., Arts and Letters, 17 (1932): 395–407.

CONTRIBUTIONS TO A STUDY OF THE FUNGOUS FLORA OF NOVA SCOTIA

III. RESUPINATE HYDNACEAE *

LEWIS E. WEHMEYER AND KAREL CEJP

THE following list includes the collections of the resupinate Hydnaceae made by the senior author in the Province of Nova Scotia. A general consideration of the points of mycological interest in regard to this Province and a description of localities will be found in the first paper on this subject (4). These collections have been studied, and most of them identified, by the junior author; under each collection the person who made the determination is indicated. The senior author is responsible for most of the microscopical data and for the descriptions of fresh material. Species not previously reported from the province are indicated by an asterisk (*). In the following list the numbers are those of the field collections. All specimens are from Colchester County except as otherwise indicated.

Portions of all collections are deposited both in the senior author's herbarium and in the Herbarium of the University of Michigan.

List of Species

*Radulum orbiculare Fr. — On *Betula alba*, Upper Brookside, July 13, 1931 (1495), det. K. Cejp.

Arising as small orbicular, "primuline-yellow" to "antimony-yellow" [1] patches with a white byssoid margin. The central areas become irregularly tuberculate or somewhat toothed in age and dry a pale brown. Spores long-cylindric, apiculate, hyaline, $7-10 \times 2.5-3.5\ \mu$.

*Grandinia farinacea (Pers.) Bourd. & Galz. — In insect borings

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 472.

[1] Color names in quotes are taken from R. Ridgway, *Color Standards and Color Nomenclature*, Washington, D.C., 1912.

in much-decayed wood, Earltown Road, August 22, 1931 (1425), det. K. Cejp; on Betula, Victoria Park, Truro, August 30, 1933 (1644), det. M. A. Donk.

Creamy white, context very thin, floccose-pruinose, with minute teeth 100–300 μ in length. Margin floccose-pulverulent, white. Spores subglobose with a single guttula, $2.5-3 \times 2-2.5$ μ, minutely asperulate when mature.

*Acia fusco-atra (Fr.) Pat. (*Mycoacia fusco-atra* (Fr.) Donk). — On decayed sticks, Upper Brookside, July 19, 1929 (59), det. K. Cejp; July 14, 1933 (1583), det. M. A. Donk (*sub* Mycoacia).

Margin bluish gray, pruinose. Teeth terete, fleshy, grayish white, becoming yellowish to red-brown or blackish upon drying. Apex of teeth with slightly projecting, enlarged, encrusted hyphae. Small, pointed, hyaline cystidioles, 16×3 μ, sometimes sparsely present. Spores ellipsoid, hyaline, $3-4.5 \times 1.5-2$ μ.

European specimens (Czechoslovakia, France, Netherlands, Poland) quite similar; American specimen with more strongly colored trama and teeth nearly black-brown when dried.

*Odontia arguta (Fr.) Quél. — On much-decayed wood, especially within the roots and bases of old stumps. Folleigh Lake, July 20, 1931 (1101); Upper Brookside, July 19, 1929 (166); Salmon River, August 1, 1931 (1201), det. K. Cejp.

Cream color to tan with a white, pruinose-pubescent margin, coriaceous, papery. Teeth quite variable in size and formation. Some of them scarcely visible, others up to 2 mm. in length, usually broad, flattened or compound, others poroid (No. 1101), approaching those of *Irpex deformis*, as given by Bourdot and Galzin (2, p. 427). The capitate cystidioles with apical resinous globules, $5-9$ μ in diameter, were seen in all collections, but were much more numerous in some than in others. In No. 166 they were abundant in the trama as well as in the hymenium. Nos. 166 and 1201 showed a few thick-walled bottle-necked cystidioles, but these were not encrusted, as given for *O. arguta* by some writers. Nos. 1101 and 166 showed protruding hyphal elements in the hymenium which were encrusted in 1101 but not in 166. Spores subglobose, hyaline, $3.5-5 \times 3-3.5$ μ.

*Odontia bicolor (Alb. & Schw.) Bres. — On decayed conifer log, Upper Brookside, July 19, 1929 (134), det. K. Cejp.

Bluish white to grayish white at first and about the margin, becoming yellowish toward the center or in age. Teeth minute, scattered, papillate at first becoming pointed or branched, penicillate at the apex, $100-250 \times 40-150\ \mu$. Context very sparse. There are two types of capitate cystidioles, one with an apical resinous or oily globule, $9-10\ \mu$ in diameter, and a second with an echinulate, crystalline tip, $3.5-5\ \mu$ in diameter. Spores oblong-ellipsoid, often flattened on one side, apiculate, hyaline, $3-5 \times 1.5-2\ \mu$.

*Odontia crustosa (Pers.) Quél. — On Fagus, Upper Brookside, July 10, 1931 (483), and July 1, 1931 (349); on *Abies balsamea*, August 12, 1931 (1289), det. K. Cejp; on *Sambucus racemosa*, July 9, 1931 (462), det. L. E. Wehmeyer.

Pale cream to ochraceous, drying light brown, margin white, minutely floccose-fimbriate, surface often cracking. Teeth as minute warts at first, becoming short, stout, and compound. The hymenium contains few or numerous small hyaline cystidioles, $15-25 \times 2-3\ \mu$, with abruptly contracted, tapered tips which barely project above the surface. Spores ellipsoid to inequilateral, hyaline, often with a single guttula, and $4.5-5.5 \times 2-2.5\ \mu$.

*Odontia papillosa (Fr.) Bres. — On decayed beech, Upper Brookside, July 11 and 27, 1931 (492, 1162), det. K. Cejp.

Waxy-fleshy, whitish turning yellowish, margin thinning out, whitish, arachnoid, granular. Teeth minute, tuberculate to dentate or compound, $100–500 \times 100–300\ \mu$. Caplike cystidioles with apical resinous droplets, $6.5–8.5\ \mu$ in diameter, were seen in No. 1162, but not in No. 492. When treated with potassium iodide or chloral hydrate, there appeared in the hymenium pointed awl-shaped hyphae which are probably the cystidioles with the droplets dissolved away. The teeth are penicillate with protruding hyphae which are encrusted with large crystalline granules. Spores oblong-ellipsoid, hyaline, $4 \times 2.5\ \mu$.

Microscopically this species resembles *O. arguta*, but it is more waxy and has smaller, more granular, not flattened teeth. These specimens agree with European material (3, p. 39). The species is especially destructive to beech and oak wood and often spreads out over the adjacent humus and débris.

Mycoleptodon fimbriatum (Pers.) Bourd. & Galz. — On decayed

wood, Upper Brookside, July 17, 1931 (1074), det. L. E. Wehmeyer.

Fairly common on decayed wood.

*Mycoleptodon ochraceum (Pers.) Pat. (*Hydnum ochraceum* Pers., *H. alnicolum* Velenovsky, Leptodon Quél., *Steccherinum ochraceum* (Pers.) Gray). — On *Alnus sp.*, Victoria Park, Truro, July 23, 1931 (1120), det. K. Cejp.

Widely effuse with rounded white margins, membranous-tough, easily separable, "ochraceous salmon" or "capucine-orange" to "Mikado-orange" when fresh, fading upon drying. Teeth fimbriate when young but not when mature. Cystidia numerous, hyaline, encrusted, 10–60 × 7 μ. Tramal hyphae with somewhat thickened walls. Spores ovoid, hyaline, 3–4 × 1.5–2.5 μ.

Fructifications much more effuse than those in European material.

*Hydnochaete olivaceum (Schw.) Banker. — On coniferous twigs, Wabii Lake, Shelburne Co., August 19, 1928 (1496), coll. C. E. Atwood, det. L. E. Wehmeyer.

This species is found in the literature under various names, commonly as *Irpex cinnamomeus* or *I. fuscescens*. The combination given above is in accordance with Banker's study (1) of this species.

*Irpex tulipifera (Schw.) Fr. — On Fagus, Upper Brookside, July 24, 1929 (103) and July 29, 1931 (323); on Betula, Salmon River, July 14, 1931 (1027), det. L. E. Wehmeyer.

Common upon dead twigs and limbs.

*Phlebia radiata Fr. — On Fagus, Upper Brookside, July 10, 1931, *fide* M. A. Donk (484).

*Phlebia strigosa-zonata (Schw.) Lloyd. — On Populus, Folleigh Lake, July 20, 1931 (1109), det. L. E. Wehmeyer.

University of Michigan

LITERATURE CITED

1. Banker, H. J. 1914. Type Studies in the Hydnaceae. VII. The Genera Asterodon and Hydnochaete. Mycologia, 6 : 231–234.
2. Bourdot, H., and Galzin, A. 1928. Hyménomycètes de France, pp. 1–761. Paris.
3. Cejp, K. Monografie Hydnaceí Republiky československé. Praha, Česká Akademie, 1928–30 : 1–107.
4. Wehmeyer, L. E. 1935. Contributions to a Study of the Fungous Flora of Nova Scotia. I. Pap. Mich. Acad. Sci., Arts and Letters, 20 (1934) : 233–266.

VEGETATIVE ANATOMY OF THE TOMATO (*LYCOPERSICUM ESCULENTUM* MILL.)

I. STEM STRUCTURE

EDWARD F. WOODCOCK

A STUDY of the literature on Solanaceae, the family to which the tomato belongs, shows a lack of information on the vegetative anatomy of *Lycopersicum esculentum* Mill. Much has been written about its culture, genetics, and pathology, but very little about its anatomy.

The early investigators confined their attention to the xylem of plants, since this tissue is the most easily seen with low magnification. Later, sieve tubes were studied, and Hanstein (2) was the first to report their occurrence in the Solanaceae. Peterson (4) discusses the distribution and the relative amount of external and internal phloem in different genera of Solanaceae, but he does not mention the genus Lycopersicum. Artschwager (1) gives a very complete discussion of the anatomy of the potato (*Solanum tuberosum*), a member of the Solanaceae and a close relative of the tomato. Even though the writer discovers a marked similarity in the stem structure of the two plants he finds no mention of that fact in Artschwager's work. King (3) describes the root-stem transition in the tomato and considers it similar to that described by Artschwager (1) for the potato.

MATERIAL AND METHODS OF INVESTIGATION

The material for study was obtained from plants grown from seed in the greenhouse. Microtome sections of the stem from 10 to 14 microns thick were stained with Bismarck brown and methyl green. A check on the path of the vascular bundles through the stem and on the method of branching was obtained by studying segments of the stem which had been fixed, dehydrated, and cleared in xylol.

ANATOMY OF THE STEM

A cross section of the stem before secondary thickening has begun shows (Pl. XXIX, Fig. 3) a circle of vascular bundles, limited on the outside by the endodermis and the pericycle and on the inside by the pith.

The epidermis is separated from the collenchyma of the cortex by a subepidermal layer one cell thick, which is thin-walled and loosely arranged (Fig. 4). The presence of this layer of cells permits easy removal of the epidermis. The stomata occur irregularly arranged on the stem, each stoma located at the top of a slight elevation. The guard cells show typical wall thickening, and are located directly above a substomatal air space. The anticlinal walls of the epidermis are quite straight in contrast to the wavy condition evident in the leaf epidermis. The numerous hairs which arise from the epidermis vary in kind and shape. The longest are several-celled, unbranched, and pointed. These hairs are from 3 to 4 mm. in length and are set in a rosette of cells which rises above the level of the epidermis. Another pointed hair, which is quite similar to the foregoing, is about 1 mm. in length and arises as a direct outgrowth from the outer wall of the epidermal cell. In addition to the pointed types of hairs there are three gland-tipped types. One of these is slightly shorter than the hair last described and has at its tip a somewhat enlarged gland cell. The other two have a multicellular gland-tipped portion. One of these consists of a single basal cell supporting a multicellular portion, which is composed of irregularly arranged cells. The other has a glandular terminal region made up of four uniform, somewhat rounded cells, which are radially arranged about the tip of the one- or two-celled hair axis. The glandular portion of the epidermal hairs contains an oily material which, when released upon rupture of the gland, gives the characteristic odor and the yellowish green stain evident when a person handles the plants.

The collenchyma region (Fig. 4), which is several cells in thickness, forms a continuous layer around the stem. The wall thickening on the longitudinal walls is localized at the corners of the cells. In a few cases the wall thickening extends across the tangential wall and gives the collenchyma a stratified appearance. The collenchyma cells either abut directly on the endodermis, which is

made up of thin-walled cells with slightly developed casparian strips, or may be separated by one or two parenchyma cells.

The vascular cylinder is not of uniform thickness throughout (Fig. 3); projections into the pith occur at intervals. The bundles which form these projections are in part free and in part connected by interfascicular cambium. Although the stem is nearly circular in cross section, there are three large bundles and between each two of these there is a smaller bundle.

The bicollateral arrangement of the vascular tissues is seen in both the larger and the smaller bundles of the stem. In cross section a small bundle appears, as shown in Plate XXVIII, Figure 1. The tracheary elements of the primary xylem appear as thick-walled structures, separated by xylem parenchyma cells. A longitudinal section of the bundle (Fig. 4) shows the primary xylem to consist of narrow, distorted ringed and spiral protoxylem elements and broad metaxylem ringed elements in which the rings are closely placed or merge into the netted type. At more or less equal distance from the outside and the inside of the xylem are small groups of thin-walled cells, which make up the phloem. Several layers of uniform, rectangular cells, the cambium zone, separate the external phloem from the xylem. The internal phloem groups are separated from each other and the xylem by thin-walled, irregular cells. This small-celled region, in which the internal phloem is located, forms what may be termed the perimedullary zone. The external phloem groups are separated from each other and from the endodermis by parenchymatous cells, which are of irregular size and constitute the pericyclic region of the stele. The phloem in both regions is made up of cell groups, which in the outer zone are small and form a fairly continuous band and which in the inner zone are more varied in size and more scattered.

The phloem consists of small groups of sieve tubes with their companion cells and conducting parenchyma. A longitudinal section of the vascular bundle through the phloem and xylem (Fig. 4) shows the cross walls of the sieve tubes thickened to form the sieve plates. A prominent nucleus is evident in each segment of the sieve tube, and also associated with the tube may be seen a narrow companion cell.

The arrangement of the vascular tissue as it follows a longitudinal course through the stem is closely related to the scheme of phyllo-

toxis. The bundles remain at approximately the same distance from the center in their vertical course through the stem, and enter the leaf as a whole or in part. Those bundles which pass into the

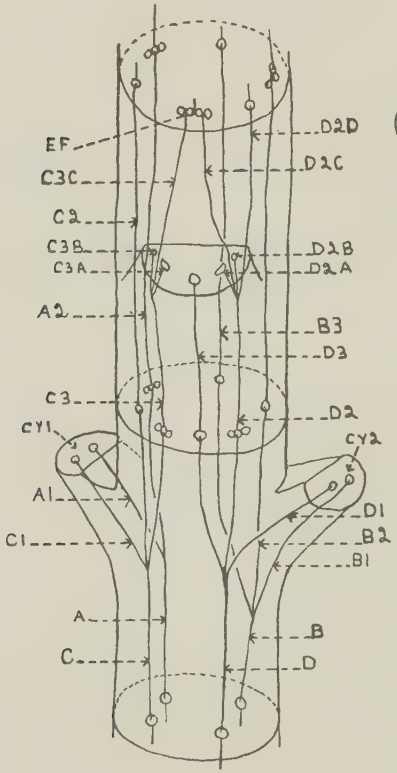

Fig. 18

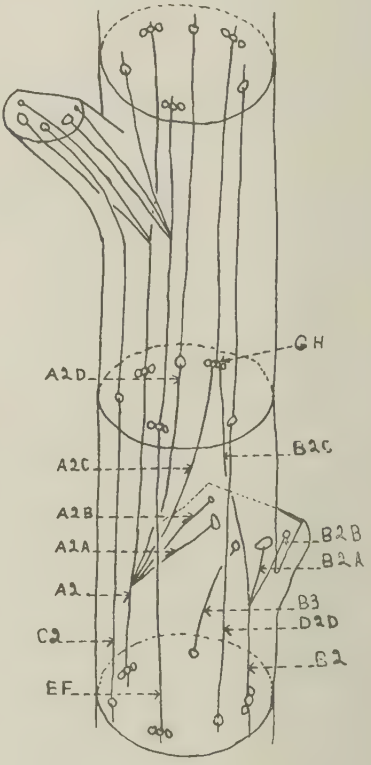

Fig. 19

Fig. 18. Diagram to show arrangement of bundles in hypocotyl, cotyledon node, and first leaf node

Fig. 19. Arrangement of bundles in second and third leaf nodes

leaf are known as leaf-trace bundles. Their relation to the bundles in the stem is of much importance. The diagram (Figs. 18 19) and the photomicrographs (Pl. XXIX) show the origin and the course of the various traces and their relation to each other and the stem. A study of the petiole cross section (Pl. XXIX, Figs. 1 2) shows that

the vascular tissue consists of a semicircular area composed of five groups. Three of these groups are large and two small, the latter lying in the corners of the petiole.

The hypocotyl is traversed by four bundles (Pl. XXIX, Fig. 3, and text Figs. 18–19), which originate from the diarch radial bundle of the root. At the base of the two cotyledons *CY1* and *CY2* these four bundles divide to form the cotyledon traces and the vascular supply above the cotyledon zone. Bundle *A* gives off the cotyledon trace *A1* and continues beyond the cotyledon node to form the large stem bundle *A2*, which gives off branches to form half the lateral traces of the second and third leaf petioles. It also gives off at each of these two nodes a small stem bundle. Bundle *B* gives rise to the cotyledon trace *B1*, to the small bundle *B3*, which forms the median trace of the second leaf, and to the large stem bundle *B2*, which gives off branches to form half of the lateral traces of the second leaf, that is, *B2A* and *B2B*. This bundle *B2* continues above the second leaf node as *B2C*, to enter into the formation of the large stem bundle *GH*. Bundle *C* gives rise to cotyledon trace *C1*, to a small stem bundle *C2*, which continues through the stem to form the median trace of the third leaf, and to a large stem bundle *C3*, which gives off branches to form the lateral traces *C3A* and *C3B* of the first leaf. Bundle *C3* continues past the first node as *C3C* and enters into the formation of the large stem bundle *EF*. Bundle *D* produces the cotyledon trace *D1* and the median leaf trace *D3* of the first leaf. Figure 2 of Plate XXVIII shows the origin of the median trace of the first leaf. Bundle *D* also continues on to form the large stem bundle *D2*, which divides into four branches at the first leaf node. Two of these branches, *D2A* and *D2B*, form lateral leaf traces of the first leaf, a third continues on to form a small stem bundle, and a fourth, *D2C*, enters into the formation of the large stem bundle *EF*.

It is evident from these data that the vascular tissue of the petiole is derived from two main sources: (1) one of the smaller bundles of the stem, which forms the median trace of the leaf petiole; (2) branches of the large stem groups, which form the four lateral traces.

The behavior of the bundles passing through the stem may be summarized as follows:

1. The median trace passes through three internodes without fusion or division, and then passes into the petiole without branching.

2. The lateral traces of the leaf petiole are given off at the node from two of the three large stem groups.

3. The method of derivation is the same for all leaves; the bundles concerned each time are a different pair from those supplying the leaf below. In the right spiral (see Figs. 18–19) the right member of the set supplying a leaf also serves as a supply for the leaf above, where it becomes the left member of the set. The median leaf petiole trace of a given leaf arises just below the third node below the leaf which it supplies.

SUMMARY

The tomato stem has an epidermis which is one cell in thickness and which is separated from the continuous collenchyma region by a somewhat loosely arranged layer of parenchyma cells. The endodermis underneath the cortex can be identified by its casparian strips. The primary vascular tissue of the stele is made up of three large bicollateral bundles and, between each two of these, a small bicollateral bundle. These bundles are connected by interfascicular cambium and have the external and the internal phloem arranged in groups separated from each other by a few parenchyma cells. The hypocotyl has four vascular bundles, which give off branches at the cotyledon node, and also give rise to the six bundles of the stem. Each of the small bundles of the stem always ends as a median leaf trace. The lateral leaf traces are derived from pairs of large stem bundles.

The writer finds a marked similarity in the structure of the tomato stem and that of the potato stem described by Artschwager.

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LITERATURE CITED

1. Artschwager, E. F. 1918. Anatomy of the Potato Plant with Special Reference to the Ontogeny of the Vascular System. Journ. Agric. Res., 14: 221–252.

2. Hanstein, J. L. E. R. von. 1864. Die Milchsaftgefässe und die verwandten Organe der Rinde, 92 pages, 10 pls. Berlin.

3. King, Effie. 1930. Root-Stem Transition in the Axis of *Lycopersicum esculentum*. Unpublished thesis, University of Chicago.

4. Peterson, O. G. 1882. Über das Auftreten bicollateraler Gefässbündel in verschiedenen Pflanzenfamilien und über den Werth derselben für die Systematik. Bot. Jahrb. (Engler), 3 (4): 359–402, pls. 4–8.

EXPLANATION OF PLATES XXVIII–XXIX

Stem of *Lycopersicum esculentum* Mill.

The following abbreviations are used on the photomicrographs in Plates XXVIII and XXIX: C, fascicular cambium; EN, endodermis; EP, external phloem; EPI, epidermis; HB, hypocotyl bundle; IC, interfascicular cambium; IP, internal phloem; MT, median leaf trace; MX, metaxylem; PE, petiole; PM, perimedullary region; PX, protoxylem; S, stoma; SE, subepidermal layer; ST, sieve tube; XP, xylem parenchyma.

PLATE XXVIII

FIG. 1. Cross section through small bicollateral vascular bundle, showing external phloem, internal phloem, primary xylem, fascicular cambium, interfascicular cambium, xylem parenchyma, and perimedullary region. × 135

FIG. 2. Cleared first leaf node, showing course of vascular bundles. × 7

FIG. 3. Cleared hypocotyledon region, showing the course of the four bundles and the origin of adventitious roots. × 7

FIG. 4. Median longitudinal section through a bundle similar to the one shown in Figure 1. Note the sieve tubes with sieve plates and the nucleus evident in one of the tube cells. The thin longitudinal walls of protoxylem are pushed in between the rings of the tube. × 150

PLATE XXVIII

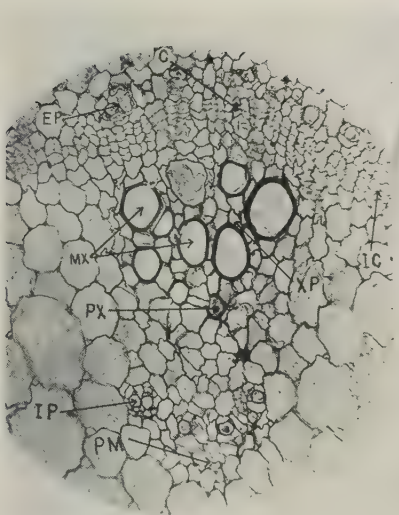

Fig. 1

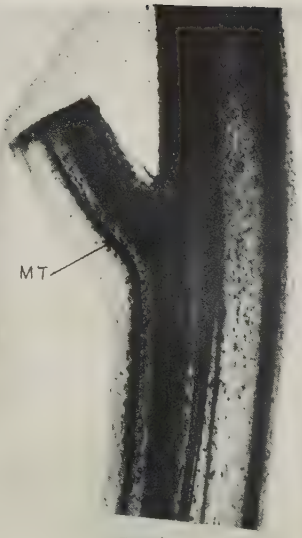

Fig. 2

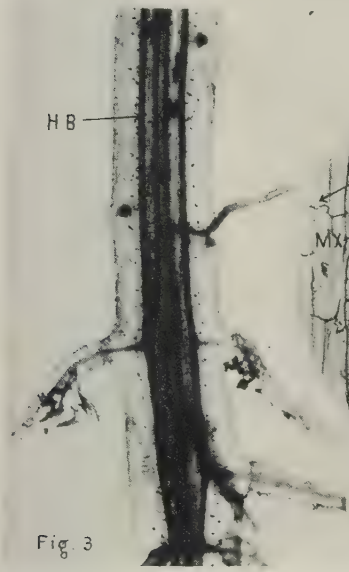

Fig. 3

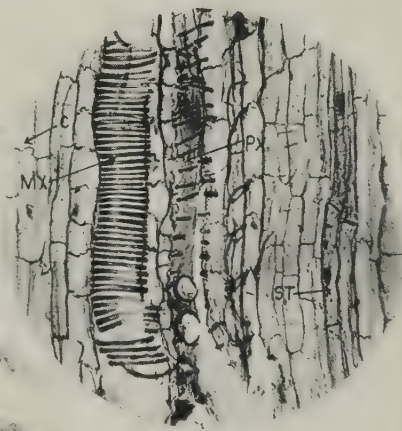

Fig. 4

PLATE XXIX

FIG. 1. Cross section of stem just above the first leaf node. Cross section of petiole also included in the figure. × 12

FIG. 2. Cross section of stem through first leaf node, showing origin of the axillary bud. × 12

FIG. 3. Cross section of stem just below the first leaf node. The two large stem bundles in the base of the bulged portion of the stem have arisen by the division of a single stem bundle. At the lower left may be seen another large stem bundle and above that a small median leaf trace bundle. × 12

FIG. 4. Cross section through collenchyma region showing epidermis, stoma, subepidermal layer, wall thickening of collenchyma cells, endodermis, and external phloem groups. × 200

PLATE XXIX

Fig. 1

Fig. 2

Fig. 3

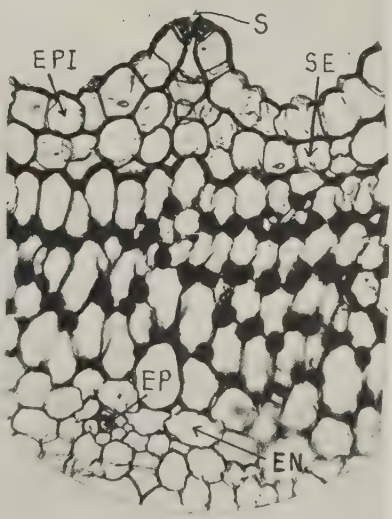

Fig. 4

RECENT FISCAL POLICY IN MICHIGAN

ROBERT S. FORD

THE fiscal policy of the State of Michigan within recent years should be viewed in the light of changing economic conditions. From this standpoint the policy becomes more understandable as well as more defensible. The problem of adapting the fiscal machinery to the requirements of a period of economic depression was made more difficult because of the antiquated character of the tax system. Furthermore, the system of taxation is very inflexible and inelastic. The condition of elasticity is illustrated in the case of New York State, where a deficit of $100 million, which had accumulated during a period of three years, was eliminated within one year.[1] Although this represents a more heroic policy than most states would follow, it is indicative of the rapidity with which maladjustments may be corrected.

The condition of inflexibility arises out of the great reliance on the general property tax. In the year 1932, for example, the property-tax levy amounted to 73 per cent of the total state and local revenues. In the same year state and local collections of property taxes represented approximately 60 per cent of total state and local revenues. In the localities the property tax accounted for almost 84 per cent of total state and local revenues.[2] To discuss the Michigan tax situation, therefore, is to discuss the operation of the general property tax, because it is basic to the fiscal structure.

The tax problem underlying the recent change in policy is of a twofold nature and may be summarized briefly as follows: first, reliance on the general property tax as a major source of revenue and, secondly, a more rapid decline in revenues than in expenditures. In the four-year fiscal period 1930–33 total state revenues declined

[1] New York State Commission for the Revision of the Tax Laws, Legislative Document No. 56 (1934), p. 13.

[2] Caverly, H. L., *A Survey of the Tax Situation in Michigan* (1933), p. 13.

40 per cent, while expenditures of the state government decreased only about 16 per cent.[3]

The great reliance on the general property tax has magnified two other associated problems, namely, the decline in assessed valuations and levies, and the increase in tax delinquency; these two factors account largely for the inadequacy of the general property tax during the depression.

NATURE OF THE TAX PROBLEM

Decline in Assessed Valuations and Levies

The decline in assessed valuations and levies in the past few years has created considerable pressure on the various governmental units. The total assessed valuation for real and personal property combined dropped from approximately $8½ billion in 1930 to $5¾ billion in 1933,[4] which represents a decrease of 32 per cent. For the state as a whole the total tax levy declined from $266¾ million in 1930 to $159 million in 1933,[4] or about 40 per cent. Entering into the decrease in the levy was the reduction of the state property-tax levy from $29½ million to $3½ million. Ranking next to the decline in the state levy was the decrease in the tax levy for school districts, which amounted to about 28 per cent.

Delinquency

Tax delinquency has likewise played a major rôle in the recent fiscal difficulties. The total amount of delinquent taxes in Michigan was estimated by the United States Bureau of the Census, as of June 30, 1933, to amount to approximately $88 million. Expressed as the ratio of tax collections to the total levy, this figure represented a 40.5 per cent delinquency for the State of Michigan as compared with 20.5 per cent delinquency for the United States as a whole. The delinquency for the east-north-central section, consisting of the states of Ohio, Indiana, Illinois, Michigan, and Wisconsin, amounted to 32.4 per cent. Of the Census Bureau estimate of delinquency in Michigan slightly more than one half, or approximately $47 million in taxes, was delinquent in Wayne County.[5]

[3] State Administrative Board.

[4] State Tax Commission. In 1933 the levels of both assessed valuations and levies were below those of 1923.

[5] United States Department of Commerce, Bureau of the Census, *Current Tax Delinquency*, Part I (1933), pp. 6 f.

In February, 1935, the auditor-general of Michigan estimated the total delinquency load to be approximately $283 million,[6] excluding the six cities that collect delinquent taxes directly, namely, Detroit, Battle Creek, Grand Rapids, Kalamazoo, Coldwater, and Berkley. In some of the localities tax delinquency reached a point where collections amounted to only 17 or 20 per cent of the levy. When it is considered that the property tax accounts for about 85 per cent of local revenues, the serious character of the situation can be appreciated.

POLICY OF DRIFT

Prior to 1933 hardly any effort was made to meet the fiscal situation, which was rapidly becoming more serious. Along the line of expenditure reduction the legislature, in a special session, in 1932 reduced state appropriations by 15 per cent. A few minor changes were made in the revenue system. In 1929 the malt and aviation gasoline taxes were adopted, although the present taxing measures date from the amendments of 1931. In 1931 an additional bracket was added to the inheritance tax in order to take full advantage of the 80 per cent Federal credit provision. These measures represent the only efforts to increase state revenues prior to July, 1933.

By the close of the fiscal year 1933 the situation had become acute. At that time the General Fund deficit amounted to $13.1 million, as compared with $5.1 million in 1932; there had been a deficit in the General Fund every year since 1929.[7] It was in this fiscal year also that total revenues of the state government reached their low point of $92½ million, while total expenditures amounted to $106½ million. Faced with these conditions, the legislature was forced to take immediate action.

POLICIES ADOPTED

The year 1933 marked the turning point in the adoption of measures of a remedial nature. However, in the attempt to meet the situation there was no coördinated policy of reform; it was more

[6] It is doubtful that the amount of delinquency increased by $200 million during the period 1933 to 1935, as a comparison of the figures of the Census Bureau and the auditor-general would indicate. At present a study of delinquency for the county property tax is being made by the Michigan Municipal League.

[7] Annual Reports of the State Treasurer.

in the nature of a series of disconnected measures designed to bolster up the points of greatest weakness. Although it was not a legislative measure, one of the first steps to be taken was the adoption of the property-tax rate limitation.

Fifteen-Mill Limitation

In November, 1932, the 15-mill property-tax limitation amendment to the Constitution was adopted, to become effective December 8, 1932. It was provided that the limitation should not apply to taxes levied in the year 1932, or to taxes levied for the payment of interest and principal on obligations incurred prior to the effective date of the amendment. At the time of the adoption of the limitation the total state and local debt amounted to approximately three quarters of a billion dollars, so that the exclusion of this factor from the maximum tax rate was of considerable significance. In 1933 the average tax rate as reported by the Tax Commission amounted to $27.39 per $1000 of assessed valuation, or 27.39 mills; of this amount 7.39 mills represented the portion for debt service, while the average tax rate for operating purposes amounted to 20 mills.

The uncertainty as to the jurisdictions covered by the limitation was settled in the so-called Pontiac case [8] in 1933, in which the Michigan Supreme Court held that all cities and villages were exempt from the operation of the limitation. The cities and villages were thus empowered to levy up to their charter limitations, which ranged from 10 to 20 mills for municipal purposes alone.

The tax-rate limitation has not been operative long enough for its full effects to be clear. Nevertheless, certain conditions have arisen which indicate to some extent the fiscal results of the limitation. In the first place, there has been a decrease in revenues from the general property tax. This has led to some reduction in expenditures, which was one of the objectives of the proponents of limitation, but such expenditure reduction has been small and came only as an indirect consequence.

Secondly, and as a corollary to the first factor, the impact of the 15-mill limitation has probably been greatest upon the public school system because of the sharp curtailment of revenues received under the Primary School Interest Fund. The public utilities, which are

[8] *School District of the City of Pontiac v. City of Pontiac*, 262 Mich. 338.

the largest contributors to this fund, are taxed at the average state tax rate. In 1933 the average state rate of taxation for all purposes was 27.39 mills, as compared with a rate of 32.796 mills in the preceding year, representing a reduction of approximately 5 mills, or 18 per cent, in the average rate.[9] The yield of the tax on the railroad companies, which accounts for the largest portion of the public utilities tax, declined from approximately $10\frac{1}{4}$ million in the fiscal year 1931 to approximately $5\frac{1}{4}$ million in the fiscal year 1933. The amount of the Primary School Interest Fund declined from approximately $24\frac{1}{2}$ million in 1930 to about $17\frac{1}{2}$ million in 1934,[10] representing a decrease of 20 per cent. In the fiscal year ending June 30, 1934, revenues totaling slightly more than $74 million were available for school support, as compared with $109 million in 1930, or a decrease of about 30 per cent. As a result of this great reduction in revenues, financing the schools has emerged as one of the most pressing fiscal problems.

Thirdly, recent adoptions by cities — Flint, Pontiac, Saginaw, Grand Rapids, Muskegon, North Muskegon, and Muskegon Heights — of the limitation will probably entail a drastic curtailment in governmental operations, and in some instances it is doubtful whether sufficient revenues will be available for operating purposes. In Pontiac, for example, expenditures have been reduced about 58 per cent during the past four years. Under the limitation it will be necessary to make a further curtailment of approximately 47 per cent. In addition, Pontiac is faced with a tax-delinquency rate of about 50 per cent.

Fourthly, short-term credit has practically been stopped because all new debts — debts incurred since December 8, 1932 — must come within the limitation of 15 mills. Many cities are unable to meet operating costs under the rate limitation, so that any increase in the tax rate for improvements is practically out of the question. Long-term borrowing is also affected because it is provided in the amendment that the vote on an increased levy shall be effective for only five years. Consequently, bonds must be limited to this maturity period.

Finally, the effect of the 15-mill limitation will be intensified because of the decline in assessed valuations. As noted previously, the total assessed valuation for real and personal property together de-

[9] State Tax Commission. [10] State Administrative Board.

clined by about 32 per cent from 1930 to 1933. In 1932 the average levy for all purposes was 32.796 mills on an assessed valuation of $6,614,308,000. In 1933 the average levy for all purposes was 27.39 mills on an assessed valuation of $5,829,284,000.[11] Within one year, therefore, there occurred a decrease of slightly more than three quarters of a billion dollars in the assessed valuation and a reduction of slightly more than 5 mills in the average state tax rate.

Tax Delinquency

Since 1932 the legislature has been attempting to provide some sort of relief for tax delinquency in order to prevent distressed home-owners from losing their property through tax sales.

At an extra session of the legislature in 1932 legislation was passed providing for the cancellation of penalties, fees, and interest charges on unpaid taxes for 1929, 1930, and 1931, if such taxes were paid within a specified period.

At a regular session of the legislature in 1933 an act was passed prohibiting the sale of lands on which taxes were delinquent for 1930 and prior years. In the same year legislation was also passed allowing delinquent taxes and special assessments to be paid in ten equal instalments on or before September 1, 1935, and annually thereafter; such payments to be made without collection fees or penalties, but with interest at 4 per cent per annum from September 1, 1935. In the estimate of delinquency which was made by the United States Census Bureau, the average rate for Michigan was set at 40.5 per cent. The delinquency rate by counties as of June 30, 1933, ranged from as low as 12 per cent in Keweenaw County to 92.5 per cent in Macomb County.[12] It seems probable that the high rate of delinquency represents partly a psychological reaction to the penalty cancellation and the moratorium in the hope that further legislative leniency may be shown. That such action is not beyond the realm of probability is indicated by the fact that a bill has been introduced in the present session of the legislature providing for the cancellation of delinquent taxes.

Sales Tax

The state was forced to abandon almost entirely the state property-tax levy because of the 15-mill limitation, the great dependence

[11] State Tax Commission. [12] See report cited in note 5, p. 224.

of the local units on the property tax, and the high rate of tax delinquency. To make up for the loss of revenue a retail sales tax was adopted in June, 1933, to become effective on July first. The act was passed for the purposes of relieving real estate from the state levy and to provide funds for the Emergency Welfare Relief.

In the act provision is made for the specific allocation of funds as follows:

State Emergency Welfare Fund for the fiscal year ending June 30, 1934	$12,000,000
General Fund for each fiscal year ending June 30, 1934 and 1935	19,000,000
University of Michigan fiscal year ending June 30, 1934, and each fiscal year thereafter	500,000
Michigan State College of Agriculture and Applied Science for fiscal year ending June 30, 1934, and each fiscal year thereafter	200,000
Total	$31,700,000

It will be observed that the allocation to the General Fund amounts to $19 million; for this amount the state relinquished a property-tax levy of about $20 million.

Specific allocation of $12 million is made to the State Emergency Welfare Fund. For the fiscal year 1934 the Michigan Emergency Relief Administration reported that approximately $42\frac{3}{4}$ million was expended; of this amount about 65 per cent was contributed by the Federal Government, about 28 per cent by the state, and about 5 per cent by the localities; in December, 1934, these proportions amounted to 75 per cent, 13 per cent, and 12 per cent, respectively. During July, August, and September of 1934 the total relief and administrative expenditures of the Relief Administration averaged about $5 million per month. The state's contribution to the relief fund is provided for by specific allocation from the sales-tax proceeds. In December, 1934, when relief expenditures amounted to $7\frac{3}{4}$ million, approximately 18 per cent of the population of Michigan was "on relief." [13]

Subsequent to the adoption of the sales tax the legislature passed an act [14] appropriating from the sales-tax proceeds, for the fiscal year ending June 30, 1934, and each year thereafter, a sum not to

[13] Michigan Emergency Relief Administration, *Monthly Bulletin on Public Relief Statistics*, December, 1934. [14] Public Acts, 1933, No. 236.

exceed $15 million for aid and support of the public schools. The public school system thus became the residual claimant to the proceeds in excess of $31,700,000, but not to exceed $15 million. In the fiscal year ending June 30, 1934, the public school system received approximately $2\frac{3}{4}$ million from the retail sales-tax fund. For it to receive the full $15 million it would be necessary for sales-tax collections to amount to $46 million, plus the amount required to defray expenses of administering the act. It has been estimated that the sales-tax collections will amount to approximately $40 million during the fiscal year 1935.

Chain-Store Tax

Shortly after the passage of the sales tax the legislature enacted a measure providing for the taxation of chain stores. Such stores were made subject to graduated license fees ranging from $10 per store in excess of one and up to three stores, $25 for each store in excess of three and up to five stores, to a maximum fee of $250 on each store in excess of twenty-five. The proceeds of the license fee were to be apportioned among the elementary schools in proportion to the number of teachers, with the qualification, however, that the apportionment to any school district, when combined with the Primary School Fund, should not exceed $800 per teacher employed in the first to eighth grades.

The constitutionality of this measure was questioned by companies such as the C. F. Smith Company, with 620 branches in Michigan; the Kroger Company, with 857 stores; and the Atlantic and Pacific Company, with 817 branches in Michigan. On March 6, 1935, the graduated license fee was upheld by the Michigan Supreme Court.[15] Under the terms of the decision approximately $700,000 in taxes which are being held in escrow will become available for state uses. In addition, it is estimated that the license fees from nonlitigants amounted to approximately $27,000 in 1933 and $145,000 in 1934. The chain-store license fees are estimated to yield between $750,000 and $1,000,000 annually.

Liquor Revenues

The Liquor Control Act became effective on December 15, 1933. In this act provision was made for the creation of a Liquor Control

[15] *C. F. Smith Company, et al., v. Frank D. Fitzgerald, et al.*, 259 N.W. 352.

Commission, and a system of control was set up which was based on a system of state-owned stores and the licensing of manufacturers and distributors. The legalization and taxation of liquor has been of considerable fiscal importance. For the period December 16, 1933, to June 30, 1934, approximately $3\frac{1}{4}$ million was derived in liquor revenues. Of this amount the net profit of the state-owned liquor stores amounted to slightly more than one million dollars; beer-tax stamps and the alcohol tax amounted to approximately $1\frac{3}{4}$ million; licenses were in excess of $400,000; miscellaneous items amounted to slightly less than $10,000.[16] Recent unofficial estimates indicate that the revenue from these four items will amount to almost $8 million for the calendar year 1934, and it is probable that a similar amount will be collected during the present fiscal year.

The act provides that in the disposition of revenues one million dollars shall be used for the creation of a special revolving fund; the balance, except for a minor amount, shall be used by the State Administrative Board in making loans to public school districts in need of funds, unless otherwise appropriated by the legislature. In the fiscal year 1934 almost one million dollars of liquor revenues was placed in the Special School Emergency Fund.

It should also be noted that on February 1, 1935, liquor sales became subject to the retail sales tax; this is estimated to yield approximately one-half million dollars a year.

Public Debt

At an extra session of the legislature in 1932 five acts were passed to cope with the situation in municipalities where defaults were imminent. Various provisions were contained in the acts for the issuing of refunding bonds for certain purposes with maturities specified. Some of the terms provided were very liberal. For example, refunding bonds issued in anticipation of the collection of special assessments could have a maturity of twenty years from the original date of the issue of the bonds, and bonds issued to refund notes issued in anticipation of the collection of taxes or special assessments might be spread over a period of ten years. Another act provided for the creation of a Public Debt Commission to prevent the occurrence of defaults in any refunding bonds issued according to the act and to protect the holders of such refunding bonds. The Commission was

[16] Liquor Control Commission.

authorized to examine the books and records of any municipality for the purpose of ascertaining whether or not it was complying with the requirements of the act.

RESULTS OF REVENUE LEGISLATION

There was a striking change during the fiscal year ended June 30, 1934, when total taxes, licenses, and fees rose from $69 million to $101 million,[17] owing to the adoption of the sales tax. In the same period total state revenues, including taxes, licenses, and fees, increased from $92½ million to $152½ million,[18] or about 64 per cent. Of the $60 million increase in total revenue, approximately $58 million was due to two factors, namely, the adoption of the sales tax and an increase in Federal aid amounting to about $24 million.

In the fiscal year 1934 state expenditures increased from $106½ million to $150 million, or about 28 per cent. Of the $43 million increase, about $35 million was due to the expansion of relief expenditures from the sum of $5.3 million in 1933 to $40.3 million in 1934.[18] The remainder of the increase is accounted for chiefly by an increase of $15 million in revenues for local units, which are collected by the state.

During the past fiscal year the General Fund revenues increased more than 100 per cent from the figure of $25.4 million to $52.1 million. Of this increase of $26½ million the sales tax accounted for $19 million. Despite the increase in General Fund revenues, the deficit as of June 30, 1934, was $13.7 million, as compared to $13.1 million in 1933.[19]

CONCLUSION

In conclusion, I think it is evident that the difficulties experienced by the state within the past few years are traceable to the great reliance placed upon the general property tax. The financial policy has been aimed at relieving the points of greatest pressure, such as the decline in revenue, the heavy property-tax burden, and increasing tax delinquency. However, most of the measures adopted in furtherance of this policy appear to be rather futile. In the first place, the 15-mill limitation is not an adequate instrument for checking expenditures and relieving the property-tax burden. Assessed valua-

[17] This figure includes sales-tax collections for a period of eleven months only.
[18] State Administrative Board.
[19] Annual Report of State Treasurer, 1934.

tions would probably have declined in any event, owing to the severity of the depression. In relatively prosperous periods the effects of such a limitation would probably be nullified by an increase in assessed valuations.

Secondly, the high rate of delinquency is a serious matter, but legislative tampering by means of a moratorium and other devices, as well as the political promise of outright cancellation, simply aggravate rather than relieve the pressure. Perhaps assessed valuations on some property were too high for the years in which taxes were returned delinquent. However, outright cancellation hardly seems the proper solution of a problem involving approximately one fourth of a billion dollars. The psychological reaction to such a step would probably be very great. Moreover, it is doubtful whether cancellation or repudiation would be valid from a legal standpoint. If something must be done, it would seem more advisable to create some sort of Tax Adjustment Commission, which would investigate the whole problem of delinquency on various types of property.

Furthermore, the delinquency picture is changing, and it would be advisable perhaps to forgo further legislative tampering at present. The Michigan Municipal League is now engaged in a state-wide survey of the delinquency for county taxes over a ten-year period. The results of this survey for the sixteen counties in which the complete findings are available indicate a significant change during the fiscal year 1934. Tables have been compiled showing the ratio of current and delinquent property-tax collections to the total current county tax levy. In seven of the sixteen counties such collections exceeded 100 per cent of the levy; in four counties collections exceeded 90 per cent of the levy, and in five counties collections exceeded 80 per cent of the levy. It seems evident, therefore, that tax delinquency is decreasing despite the agitation for cancellation.

Thirdly, the sales tax was adopted because no other source of revenue was available. Presumably an income tax could have been imposed only by means of a constitutional amendment. Consequently, the burden of meeting the crisis was placed largely on those who were least able to bear it. The tax on food alone represented 28 per cent of the total sales-tax collections in the fiscal year 1934, while food and wearing apparel combined represented 35 per cent of the total.

It seems that the effects of the sales tax in relieving the burden

on property have been somewhat overestimated. The state property-tax levy, for which the sales tax was introduced as a substitute, amounted to $29½ million in 1930 and $23½ million in 1932.[20] The proceeds of the sales tax in the fiscal year 1934 exceeded $34 million,[21] representing an increase of $6 million over the high state levy of 1930. To illustrate one possible effect of the shift from the property tax to the sales tax, let it be assumed that two persons own property having a valuation of $4,000 and $10,000, and that a reduction of 3 mills is made in the tax rate; this would amount to a saving of $12 and $30 respectively on the two pieces of property. If the $4000 property owner had an income of $1,500 and spent $1,000 on items subject to the sales tax, he would pay $30 sales tax. If the $10,000 property owner had an income of $4,000 and spent $3,000 for items subject to the sales tax, he would pay sales tax in the amount of $90. The net result, according to this illustration, is that the $4,000 property owner pays $18 more in taxes, while there is an increase of $60 in taxes for the $10,000 property owner. What a person gains, therefore, in real estate relief may be more than offset by the increase in the sales-tax burden.

Finally, the taxation of liquor represents a fortuitous source of revenue which will probably increase appreciably within the next few years. A very commendable system of liquor control has been created in Michigan. Certain interests, however, are urging that the business be transferred from the state to private groups. This is based on the unsubstantiated contention that the state stores are inefficient and poorly managed.

In the attempt to meet the fiscal emergency of the past few years there has been no unified policy of tax revision. An analysis of the recent changes leads to the conclusion that the results of the new legislation have been somewhat different from those that were anticipated. Apparently the tax-rate limitation was designed to relieve property, either by transferring a portion of the tax burden on property to some other tax base or by reducing expenditures in an amount equivalent to the relief for real estate. It is true that a portion of the tax burden has been shifted from property, but in the process of the transfer there has been an increase in the total tax burden. In the cities that are now under the 15-mill limitation

[20] State Tax Commission.
[21] State Board of Tax Administration.

there is considerable agitation for the state to make additional grants-in-aid. As other cities take similar action the pressure will become even greater. The state will therefore be placed in the position of having to discover new sources of revenue. The objective of tax revision should be defined so that a definite, coördinated program could be formulated. The tax problem is an integrated problem, and it requires an integrated solution; any other type of treatment will tend to create more problems than it was designed to correct.

University of Michigan

HOW MUCH DEVELOPMENT CAN A WILDERNESS AREA ENDURE?

SHIRLEY W. ALLEN

A WILDERNESS area as I shall consider it in this paper is extensive, wild, and undeveloped, interesting because of unusual terrain and living forms and because nature may be observed at work undisturbed by man, and dedicated exclusively to recreational use.

Let us assume that one of these areas in the United States were to suffer destruction of a considerable part of its plant and animal life through an uncontrolled natural fire — one started by lightning. Few biologists, and fewer administrators of conservation enterprises, would consider this event anything but a calamity — almost the last thing they would wish to see occur. And yet nature here would be at work, or perhaps at play, undisturbed by man.

Now let us go to the entrance of another great wilderness area, characterized by rugged canyons and mountains or dangerous waters, few and poorly maintained trails, sudden and severe storms, lack of any buildings, sources of supplies, or means of communication — a real wilderness.

How many men in conservation work would feel it anything but their duty to advise all except the most seasoned explorer of wild country to stay out of such a wilderness unless he had a guide as well as pack animals or means of water transportation? The answer is, very few indeed, and even these would probably be sharply criticized for failing to warn travelers.

Our attitudes in these two situations are interesting. Nature should be undisturbed except in case of fire. The wilderness should be wild but not too inconvenient. May not these viewpoints indicate about what we think a wilderness area needs or can endure in the way of development, if it is really to be, first, preserved, and, secondly, used? "Forever in a state of nature" is a phrase which calls up a picture of wilderness, even a wilderness which has suffered from a lightning fire. Add the remainder of the quotation "for the use

and enjoyment of the people," and the wilderness picture begins to look like the unrighteous man in the Psalms (who is really the champion fadeaway artist in all literature), "Thou shalt diligently seek his place and it shall not be." The wilderness will certainly "not be," for long, under the impact of too much use and enjoyment of the people.

But recreational use of primitive country or country which has reverted to wilderness frequently involves the loss of life, health, or limb of the user and, what is less obvious, the destruction of the charm of the area itself. The latter calamity is frequently accompanied by persistent local ugliness and disorder which is all the more shocking because so far from ordinary human haunts.

Who among us cannot recall with disgust that masterpiece of convenience, the tin can, decorating in impressive numbers a spot from which the most majestic scenery is visible at a distance? Who has failed of introduction to a disemboweled mattress which some lover of comfort has left on the shore of a lake? What is worse, Who has missed the violent odors of human filth so often left uncovered about a favorite camp site in a scene otherwise perfect?

One may think of these disorderly things as isolated and fleeting, like waste discarded from ships at sea, and yet the pollution of the land persists for a long time even in unfrequented country. But there are man-caused or natural changes which are *not* fleeting. What about the meadow where pack stock could feed ten years ago and which is now one vast gully? What of an impassable trail where one meets a landslide on his way back to civilization when his supplies are about used up? To make the picture more homely, What about an early fall blizzard or a cold rain which lasts for days, with one's tentage lost in crossing a mountain torrent or along with a pack mule which was pushed over the cliff by a frightened saddle horse? These are conditions to be met in travel through a real and savage wilderness area.

Such areas will be used, however, and even enjoyed by the people. Therefore, without insisting that any wilderness area be made safe for everybody or even relatively fireproof, I should like to suggest some limits and types of development which will tend to retain the wilderness and yet make it tolerable for use by somebody other than a professional explorer.

One cannot separate the words "road" and "gasoline" for long.

The term "truck trail" is an admirable admission of this truth. (I hope we shall never see "wilderness gasoline" as a cost item on conservation records.) A road of any sort, narrow, crooked, swampy, camouflaged by a landscape architect or barred with a gate, is still a path over which to drive an automobile, and it has no place in a wilderness, even for the alleged purpose of fire control. Likewise a firebreak which can be traveled by an automobile is an example of letting down the bars. I have not seen the admirable one in Wilderness State Park, but I hope it is too rough for tourist travel.

It is important to remember that roads and wildernesses do not mix. Neither, in my opinion, do railways, funicular or other, have a place in an area which is set aside for wilderness recreational use or advertised as a wilderness area. It may be argued that cable railways have been developed to reach many of the world's most awe-inspiring points. It will be said further that thousands of people are thus allowed to see wilderness where dozens would enjoy it otherwise, but is it wilderness which they see after it is so easily penetrated? Have they really reached a wilderness?

Landing fields, emergency or fully developed, comprise another form of construction which should be excluded from wilderness country. Of course, landing fields are useful, but for what? To make accessible a wild stretch of back country to those who are interested in flying or in anything but wilderness. To reach a lightning fire with men and supplies. To find lost people. All these items of usefulness for landing fields have put the wilderness idea in the background. So the landing field is the third adjunct of quick and comfortable transportation which no real wilderness can endure.

The inn or hotel in a wilderness is almost an impossible institution without the easy means of transportation which have been mentioned — automobile road, railway, or cableway, and airplane landing field. We may therefore pass by the hotel with the observation that it might have a place on the edge of a wilderness, but not in the area itself.

Lest I should be accused of dwelling too long on the obvious, suppose we consider the fire-observation cabin or the fire tower. Surely this may be properly placed in a wilderness area, for is not prompt and accurate detection an essential of fire control? (Now we begin to surrender, for we do not want a burned wilderness.) But wait! How are we to see nature at work destroying an aged forest by

lightning or covering a fire-scarred mountain with a new type of vegetation? There is an ingenious if not a happy answer, and it is this: By continuing to observe the failures of man in lightning-fire control regardless of his detection system and his desperate efforts. He can still work at lightning-fire control, but he cannot deprive the wilderness traveler of the exhibit of these titanic scenes in nature's plan. The fire-observation headquarters may be forgiven as an invading item. It may, however, be built of native material rather than of members which suggest a power line or a village hose-cart shed.

Speaking of man's fire control efforts, how is man to control the fire set by his fellows? This is a fair question, and it may be answered by saying: Control will come through travel ways such as foot trails, horse trails, and canoe routes with occasional improved portages. The fact that these single-file routes serve the wilderness traveler who seeks out unfrequented places discounts in no sense their value as travel routes for fire fighters and patrolmen or as narrow cleared strips so valuable in fire-control strategy. They must be well located and adequately maintained, however, and their importance may justify major structures such as the cable bridge across Hamilton Gorge in the back country of Sequoia National Park, even though these must be constructed of something besides native material. So we conclude that fire control alone may make trails necessary and appropriate in a wilderness area. In passing we may pause to protest against the romantic but somewhat ridiculous tendency to designate major highways as "trails."

Should a wilderness traveler choose to use saddle and pack stock for his trip, the problem of pasture must be faced. The cowboys have a saying that a man may as well be dead as afoot. Well, afoot he will be if there is no pasture or "feed," in the western vernacular. Sometimes he will be afoot in spite of pasture and hobbles for his animals unless there is a fenced pasture. The forage problem suggests the questions: Should nature be allowed to take its course in covering meadows with forests or in destroying them with the action of streams? Should fenced pastures be considered appropriate in a wilderness area?

Consider the question of disappearing meadows, which are the principal wilderness pastures in many places. Forest will encroach upon, and natural erosion and flood will obliterate, these meadows.

The possibility of conservative clearing out of invading trees and using them to divert a stream which is depositing gravel on the meadow each spring is not nature's way. Neither is the placing of log dams or the planting of willow cuttings to forestall a gully wide as the meadow itself, nature's way. Yet these developments or man-made interferences will hardly destroy the true wilderness character of the country, and they may make it tolerable for man's use. The pasture fence is more questionable, but hardly taboo, particularly if it be from cliff to cliff across a canyon and constructed principally of native material.

There remain the questions of shelter, communication, and sanitation.

Shelters of logs or stone, crudely but substantially constructed with three walls and a good roof, may save life. Certainly they make the life of the traveler more tolerable, and they need not be frequent or conspicuous. On such a plan they are now used and they are justified.

Communication means telephone, and this is essential if a fire-lookout system is included as appropriate. Perhaps recent developments in short-wave radio will make telephone lines obsolete. If so, the scenery will be better without them.

Crude improvements at places where wilderness travelers naturally camp repeatedly are frankly a necessity. Even the most esthetically inclined will neglect his tin cans and papers. Wild animals will clean up garbage pretty well, but a pit, a good deep one, with a bear-proof cover, if possible, and a small opening, should be provided for cans. Fireplaces, piped water supply, and tables are not appropriate, but the whole spirit of the wilderness will hardly be sacrificed if a few flattened logs are available. The question of latrines in an unpoliced camp site anywhere is still not satisfactorily answered. These devices have no place in the wilderness. The decency of the wilderness traveler will have to be trusted, but from what I have seen of his credit he will be back to get his note renewed many times at the hands of the public. Here is a chance for educating the wilderness traveler. It is not always the novice or the city-bred visitor who leaves a dirty camp.

I have not mentioned direction signboards. These are appropriate even in a wilderness area if they are neat, legible, not too conspicuous, and at all times kept in repair.

Shall we say now that, if routes for power-driven devices, hotels, piped water systems, and latrines are excluded, and if trails, crude shelters, fire-lookout stations, pits for cans, occasional telephone lines, erosion and flood-control devices, pasture fences and direction signboards are allowed, we have a wilderness area acceptable for exclusive recreational use? No, but "yield not to temptation." We are looking for work projects to utilize emergency labor. We try to appraise wilderness recreation values in terms of a human span of life, not in terms of the geological periods with which nature deals. Our zeal to defend the current crop of resources may prove a boomerang to rob us of what we really want in the wilderness.

Perhaps we may state a principle of land use: The qualities which are priceless in a wilderness recreation area are threatened by any kind of human use. Recreational use, because it ministers to the spirit as well as the body, is worthy of encouragement. Others beside professional explorers should use the wilderness for recreational purposes. The minimum of development in a wilderness must include those improvements which allow man to use it with comparative safety to life, but with least modification of natural state.

University of Michigan

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. VII

DOW V. BAXTER

A MERE catalogue of all known species and forms of the resupinate wood-destroying fungi and polypores in the region of the Great Lakes offers little help to students of forest pathology, and especially of wood pathology, unless descriptions of these plants, including an account of their variations as demonstrated in culture, and a comparison with the known members of this group found elsewhere, can be presented.

It is hoped that the series of publications of which this forms a part will eventually serve as a guide to the group.[1] Keys to the common white, cinereous, yellow, red, and brown plants were presented in Papers III and IV (1, 2). These keys will be supplemented in the near future to include additional new plants and forms that are found in other regions. A classification according to certain growth characteristics of several of the resupinate polypores in culture and descriptions of several of them followed in later numbers. The present article reports the results obtained in a continuation of the monographic studies.

It was stated in Paper V (3) that the types of growth and growth rates offer valuable characters to observe in distinguishing between certain species in this group. The plants were arranged according to

[1] Throughout the work upon these monographic studies I am indebted to many individuals and institutions for help and suggestions. My appreciation is expressed particularly to Professors T. G. Halle and Gunnar Samuelson of the Riksmuseet Naturhistoriska in Stockholm, with whom I have the pleasure of association. Acknowledgment is due to Professor Torsten Lagerberg, Skogshogskolan, Experimentalfaltet, Stockholm. Mr. Seth Lundell kindly accompanied me on several field trips near Uppsala.

I am under obligation to several American scholars also: to Dr. L. O. Overholts, who has studied many plants sent to him for determination; to Dr. C. L. Shear, of the Office of Pathological Collections of the United States Department of Agriculture; and to the authorities at the New York Botanical Garden and the Missouri Botanical Garden.

their rate of growth.[2] The following resupinate polypores are added to these groups:

A. RATE OF GROWTH

Rapid growth

Poria Weirii from Thuja plicata

Poria mutans var. tenuis from Castanea dentata

Trametes serialis from "Wisconsin" *

Poria xantha forma crassa from Picea glauca

Poria incrassata from "building timber, Mississippi" *

Slow growth

Trametes malicola from Populus grandidentata

Poria pereffusa from Quercus sp.

Fomes nigrolimitatus from "Washington" *

B. RANGE OF TEMPERATURE FOR GROWTH

Large range

Poria mutans var. tenuis from Castanea dentata

Poria Weirii from Thuja plicata

Trametes malicola from Populus grandidentata

Poria pereffusa from Quercus sp.

Poria xantha forma crassa from Picea glauca

Trametes serialis from "Wisconsin" *

Poria incrassata from "building timber, Mississippi" *

Small range

Fomes nigrolimitatus from "Washington" *

* Rearranged from data presented by Humphrey and Siggers (8). Medium consisted of distilled water, 1,000 c.c.; Trommer's malt extract (plain), 25 gr.; agar-agar (Bacto, granulated), 20 gr.

[2] The terms in this classification are defined in Papers V–VI of this series.

C. TEMPERATURE FOR BEST GROWTH

High temperature

Poria mutans var. tenuis from Castanea dentata

Poria pereffusa from Quercus sp.

Poria incrassata from "building timber, Mississippi" *

Average temperature

Trametes malicola from Populus grandidentata

Poria xantha forma crassa from Picea glauca

Poria Weirii from Thuja plicata

Trametes serialis from "Wisconsin" *

Low temperature

Fomes nigrolimitatus "Washington" *

D. EFFECT OF LIGHT

Best growth in dark

Poria mutans var. tenuis from Canea tasdentata

Poria Weirii from Thuja plicata

Trametes malicola from Populus grandidentata

Poria pereffusa from Quercus sp.

Poria xantha forma crassa from Picea glauca

Data on color characteristics, texture, effect upon the agar medium, and rate of growth in the dark and the light have been presented for several resupinate polypores (2, 3). The growth features for additional plants are given in Table I and are illustrated in Plate XXX.

DESCRIPTION OF THE RESUPINATE POLYPORES

The morphological characters of the majority of the resupinate polypores have been studied in the material in various European and American herbaria. The plants, however, which are to be found in

* See the explanation of the asterisk on the preceding page.

TABLE I

GROWTH CHARACTERISTICS OF RESUPINATE POLYPORES ON MALT AGAR

NAME	IN LIGHT					IN DARK				
	Rate in mm. 14 days*	Color (Ridgway)	Texture	Agar discolor ation	Pore formation	Rate in mm 14 days*	Color (Ridgway)	Texture	Agar discolor ation	Pore formation
P. perelfusa	18	Clay color (mostly) to mummy brown (margin white)	Felty (like chamois skin)	None	None	31	White margin to light buff, warm buff	Cottony	None	None
P. Weirii	41	Pinkish buff to cinnamon-buff	Fibrous to cottony	None	None	41	Cartridge buff to cream-buff to cinnamon-buff	Cottony	None	None
P. mutans var tenuis	41	Pale pinkish buff to pinkish buff to cacpucine orange	Fibrous to slightly cottony	None	None	41	Pale pinkish buff to pinkish buff to cacpucine orange	Fibrous to slightly cottony	None	None
Poria crassa, Mt. McKinley	41	White to sea-foam yellow to massicot yellow	Slightly arachnoid to cottony	None	None in some cultures; in others slight tendency toward pore formation noted	41	White to sea foam yellow to massicot yellow	Slightly arachnoid cottony	None	None in some cultures; in others pore formation noted
T. malicola	24	White	Cottony	None	None, but observed in same growth period in flask culture	21	White	Cottony	None	None

* Cultures grown at room temperature.

my own collections from this region and from other sections of North America form the basis for most of the descriptions which follow. The records of habitat and distribution reported in this paper have been established, for the most part, from my own collections. They have been supplemented, however, by data obtained from authentic specimens found in various herbaria and from authentic published accounts as noted in Paper V.

Poria corticola (Fr.) Cooke, Grevillea, 14 : 113. 1886

Polyporus corticola Fr., Syst. Myc., 1 : 385. 1821.
Polyporus aneirinus Fr. non Somm. in Romell, Arkiv för Botanik, 11 : 21. 1911.

Fructification annual, effused for ten centimeters or more, but usually much less, not separable to separable when mature, margin white, thin, pubescent, 0.5–2 mm. wide when young, remaining sterile and often becoming membranous or fertile in mature plants; subiculum thin, white, inconspicuous, less than 0.5 mm. thick; tubes unstratified, 0.5–4 mm. long, usually shallow; mouths white when fresh, "cinnamon-buff" in herbarium specimens, frequently glistening, angular, thin-walled, entire, or sometimes becoming dentate-lacerate, 2–5 per mm., and usually 2–3 per mm.; basidia 4-spored, 5-6 × 11 μ; spores ellipsoid or oblong-ellipsoid, hyaline, smooth, frequently adhering in groups in microscopic mounts, 4–5.5 × 3–3.5 μ, 1-guttulate; hyphae flexuous, simple or seldom branched, often incrusted, 2–4 μ in diameter, occasional cross walls, no clamp connections; large conspicuous cystidia usually present, which often rise deep in the trama, incrusted, 3–7 × 11–27 (55) μ or smaller capitate organs 7 × 4 μ or both types of structures present.

Allied species. — Old long-tubed specimens of this species dry somewhat in the same manner as *Poria ambigua* — and may actually show a striking resemblance to that species.

The long-tubed forms seldom occur in the United States, but are not uncommonly found in Europe, where the plant is often effused over much greater surface areas (1.5 feet or more in length) than I have ever seen it in America. The cystidia of *P. corticola* can be used to separate it from *P. ambigua.*

P. vicina Bres. is also described as having large capitate cystidia. The spores of this species, however, are oblong, subelliptic, 6–8 × 3.5–4 μ (Bres.), whereas those of *P. corticola* are 4–5.5 × 3–3.5 μ.

Habitat. — *Acer negundo, Fagus sp., Liriodendron tulipifera, Populus acuminata, P. deltoides, P. tremuloides, P. trichocarpa, P. Sargentii, Salix sp.* Also reported on *Thuja plicata* (10).

Distribution. — British Columbia, Manitoba, Nova Scotia, Ontario, Saskatchewan, Colorado, Idaho, Iowa, Maryland, Missouri, Montana, New York, Ohio, Pennsylvania, South Dakota, Vermont, Virginia, Washington, West Virginia, Wisconsin.

Poria lenis Karst. in Sacc., Syll. Fung., 6 : 313. 1888

Poria calcea (Fr.) Bres. var. *coriacea* Bourd. & Galz., Hymen. Fr., 674. 1917.
Polyporus vulgaris Fr. pro parte sensu Romell, Svensk Botanisk Tidskrift, 20 : 20. 1926.
Polyporus vulgaris Fr. var. *calcea* pro parte sensu Bresadola, in European herbaria.
Polyporus lenis Karst. sensu Romell, Svensk Botanisk Tidskrift, 20 : 20. 1926.

Plate XXXI

(See Pl. XXII of Vol. XV, facing p. 228)

Important specimens:

Physisporus lenis Karst. on *Pinus silvestris*, Mustiala, Finland. Leg. P. A. Karsten, Herb. Bresadola, Stockholm.
Polyporus vulgaris Fr. var. *calcea* pro parte sensu Bresadola. Herb. Bresadola, Stockholm.
Polyporus lenis Karst. sensu Romell, Saltsjö-Duvnäs, Sweden. Herb. Mycolog. Lars Romell, Stockholm.

Fructification annual, sometimes living through the entire year, whitish, soft to the touch, light in weight, widely effused, generally about 0.5 meter, but often up to 3 meters or more, up to 3 mm. thick, usually less; margin white, sterile, pubescent, up to 2.5 cm. wide or soon becoming fertile; subiculum white, 0.5 mm. or less in width; tubes 1–2 mm. long; mouths white to "pinkish buff" and "ivory yellow," 3–4 mostly 4 to a mm., angular; dissepiments thin, fimbriate; basidia 10–14 × 3–5 μ; spores allantoid, so strongly curved that a half of a circle is formed, 3–5 × 1–2 (1–1.5 μ); hyphae undulate, 2–4 μ wide, often incrusted; clamp connections and cystidia not found.

Allied species. — Because both *P. lenis* and *P. sericeo-mollis* are described as soft white plants, it is well to emphasize the fact that the spores of *P. lenis* are very strongly curved. Herbarium specimens of *P. lenis* do not usually crumble, but remain somewhat tough and leathery. *P. sericeo-mollis* easily crumbles between the fingers. None of the many collections of *P. lenis* examined show

reflexed margins, a habit which is characteristic of the dried specimens of *P. sericeo-mollis.*

It is more difficult to separate *P. vulgaris* from *P. lenis* because of the many interpretations given to the former plant. Romell (11) has called attention to the fact that this Friesian name covers several distinct species. These species are kept separate in this text, and the name *P. vulgaris* Fr. is retained for the first of the following series:

(1) *P. vulgaris* Fr. — This plant can be found as *P. biguttula* in Romell's Herbarium. It is designated by Romell himself, however, as the preferable one to be regarded as *P. vulgaris.* This interpretation of the species, as Romell has pointed out, is the same as that known to have been used by Peck for American collections.

(2) *P. lenis* Karst. — The plant is described in the text under this name. The spores in this plant are strongly curved.

(3) *P. byssina* Pers. — Romell's interpretation of this plant is followed in the text. *P. byssina* Pers. *sensu* Romell is the same species which Bresadola has called *P. vulgaris* Fr. (*sensu stricto*). Macroscopically, it resembles a white form of *P. eupora.* The presence of cystidia in *P. eupora* will, of course, readily keep these two plants apart.

(4) *P. xanthus* sensu Lind. — This is the *Pol. vulgaris* of Romell in his *Hymenomycetes of Lapland,* but he later called it *Pol. xanthus.* The spores are not usually guttulate in the fresh *P. xanthus.* The sulphureous color of the tubes of *P. xantha* may be used also as a supplementary character to separate the two species in typical collections.

Habitat. — *Abies balsamea, A. grandis, Chamaecyparis nootkatensis, Picea glauca, P. sitchensis, Pinus contorta, P. radiata, P. resinosa, P. strobus, P. taeda, Pseudotsuga taxifolia, Sequoia sempervirens, Taxodium distichum, Thuja occidentalis, Tsuga canadensis, T. heterophylla.*

Distribution. — British Columbia, Ontario, Alabama, Alaska, California, Florida, Idaho, Massachusetts, Michigan, Montana, New Hampshire, New Jersey, New York, North Carolina, Tennessee, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming.

Occurrence. — *P. lenis* is very common on white pine and hemlock in the east and in the region of the Great Lakes.

In Alaska it is found on *Chamaecyparis nootkatensis*. It occurs so abundantly on this wood on Baranoff Island that it is considered to be one of the most common fungi found on this timber. Since comparatively few fungi attack this wood, it is unusually interesting that this plant is so common on this tree and that it so often extends over the entire length of fallen trunks. In resistance to decay the heartwood of *Chamaecyparis nootkatensis* is ranked with Port Orford cedar, western red cedar, redwood, and southern cypress (9).

Bald cypress, listed among the "very durable" woods (12), is also a substratum. I have made large collections of this fungus, ordinarily considered a northern one, on *Taxodium distichum* in the Big Gum swamp of northern Florida.

Poria lenis is also common on white spruce in the forests of the interior regions of Alaska. In fact, I have found it in great quantities on logs of *Picea canadensis* in the open forests along the Toklat River in Mt. McKinley National Park.

Decay. — Decayed wood infected by this fungus is characterized by the abundant occurrence and copious growth of white, woolly hyphae, which spread over the surface and fill the cracks in the rotten wood. The mycelium grows between the annual ring layers. The dried wood is very light in weight. In tangential section the wood appears to be finely honeycombed with narrow, irregular pockets, which follow the grain. These pockets may be microscopic, measuring 61 × 37 μ or smaller up to macroscopically visible areas 25 mm. long and mostly 0.5–1.0 mm. wide. The pockets are formed by the breaking down of one to five or sometimes more tracheal walls. The thin-walled and sparsely septate-branched mycelium usually fills these areas and forms mats or wefts, which may be seen by the unaided eye.

Poria papyracea (Schw.) Cooke, Grevillea, 14 : 111. 1886

Boletus papyraceus Schw., Naturforsch. Ges. Leipzig Schrift., 1 : 99. 1882.
P. barbaeformis Bark. & Curt.

(See Pl. XIX, Fig. 1, of Vol. XV, facing p. 228)

Fructification annual, 1 mm. thick or less, appearing in orbicular patches, usually about 2 3.5 cm. long and rarely longer than 6 cm., 0.5-2 cm. wide; margin white, pubescent; subiculum less than 0.3 mm. thick, white, tubes less than 0.5 mm. long; mouths white

to "pinkish buff" in dried specimens, angular, 2–3 mostly 2 to a mm.; dissepiments rather thick, entire; basidia 4-spored, 6 × 8–10 μ; spores cylindric, hyaline, echinulate, 11–15 × 6–9 μ; hyphae occasionally branched, no cross walls evident, no clamp connections, mostly 3–4 μ in diameter; no cystidia.

Allied species. — This species is not readily confused with any other resupinate polypore. The broad, elongate, and striated or echinulate spores enable one to distinguish this plant.

Habitat. — *Chamaecyparis thyoides, Thuja occidentalis, Vitus sp.*

Distribution. — Alabama, Kentucky, Maine, Michigan, Minnesota, New York, North Carolina, Virginia, Wisconsin.

Occurrence. — This plant, once supposed to be rare, is not uncommon in northern Michigan on *Thuja occidentalis;* the largest collections have been made on the islands in the northern region of the Great Lakes.

Poria punctata Fries, Hymen. Eur., 572. 1874

Poria Friesiana Bres., Ann. Myc., 6 : 40. 1908.
Fomitiporia laminata Murr., North Am. Fl., 9 : 11. 1907.
Fomitiporia obliquiformis Murr., North Am. Fl., 9 : 9. 1907.
Poria laminata (Murr.) Sacc. & Trott., Sylloge Fung., 21 : 336. 1912.

Plate XXXII, Figure 1

(See also Pl. II of Vol. VI, facing p. 76, and Pl. IX, Fig. 2, of Vol. XIX, facing p. 332)

Important specimens:

Poria Friesiana Bres. on *Salix cinerea*, from Bourdot, Herb. Bresadola, Stockholm.
Fomitiporia laminata Murr. on *Alnus sp.*, W. A. Murrill, Piscataquis Co., Maine, 1905. Herb. New York Botanical Garden.
Fomitiporia obliquiformis Murr. on hardwood logs, A. P. Morgan 30, Cincinnati. Herb. New York Botanical Garden.

Fructification perennial, effused for several centimeters, adnate and never loosening from the substratum, often cracking on drying, 0.5–10 mm. thick; margin narrow, 0.5–1 mm. wide in young specimens and mostly disappearing in old plants; subiculum thin, largely disappearing with age; tubes 0.5–3 mm. long each season, soon stuffed with whitish mycelium; mouths "wood brown," "antique brown," round, thick-walled, entire, averaging 4–7 mostly 5 to a mm., dissepiments 44–99 μ; basidia inflated 7–8 × 9–13 μ, mostly 7 × 9 μ, i.e. almost as wide as long, hyaline, 2–4-spored; spores hyaline, smooth, globose or subglobose,

1-guttulate, 5–6 μ, rarely 8 μ; setae absent; cystidia-like hyphae with enlarged or bulbous bases projecting from the hymenial surface; hyphae brown, flexuous, rarely septate, no clamp connections, cross walls visible, 2–4 μ in diameter.

Allied species. — *P. punctata* is difficult to distinguish from *F. igniarius* var. *laevigatus*. Setae are not found in *P. punctata*, but they occur in *F. igniarius* var. *laevigatus*, though they may be infrequent even in this plant.

Cultures. — Isolated from *Rhus toxicodendron*, Pinckney, Michigan. Cultures exhibit a flocculent aërial mycelium, distinctly cottony in appearance. Twenty-four-day-old cultures are "cream-buff" to "Isabella color." See Paper V (3) of this series for further discussion of the growth characteristics.

Remarks. — The fruiting bodies, unlike those of many resupinate polypores, are commonly found on standing dead wood.

Habitat. — *Acer rubrum, A. saccharum, Alnus sp., Asimina triloba, Berberis vulgaris, Buxus sempervirens, Castanea dentata, Cercis canadensis, Corylus avellana, Fagus grandifolia, Fraxinus americana, F. sambucifolia, Juglans cinerea, Kalmia latifolia, Liquidambar styraciflua, Ostrya virginiana, Physocarpus opulifolius, Populus trichocarpa, Quercus rubra, Q. virginiana, Rhus vernix, Robinia pseudoaccacia, Salix amygdaloides, Sassafras sassafras, Tilia americana, Toxylon pomiferum, Viburnum lentago, V. prunifolium.*

Distribution. — Manitoba, Nova Scotia, Ontario, Quebec, Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New York, North Carolina, North Dakota, Ohio, Pennsylvania, Texas, Vermont, Virginia, West Virginia.

Occurrence. — One of the most common porias of the region.

Decay. — Wood destroyed by this fungus becomes whitish as it dries out. Although the mycelium may be found in all the elements of the rotten wood, the hyphae do not occur abundantly in the badly decayed areas, which are not directly beneath the fruiting body. The mycelium in the wood consists of small hyaline hyphae, which branch freely. Most of the hyphae measure 1–2 μ wide. Brownish deposits, "decomposition products," are to be found in the wood decayed by this fungus.

Polyporus flavicans Karst.

Polyporus nitidus Fr. pro parte in herb. not unpublished photograph.

Plate XXXII, Figure 2

Important specimens:

Poria flavicans Karst. on *Picea excelsa* prope Kristianiam, Herb. Bresadola, Stockholm.

Polyporus (*Poria*) *flavicans* Karst. on *Picea excelsa*, det. Romell. (*Poria crassa* Karst., det. Bresadola), Norwegen, Holmenkollen, 1909. Ex. Herb. J. Egeland, Herb. Mycolog. Lars Romell, Stockholm.

Poria flavicans Karst. on *Picea excelsa*, Norwegen, Kristiania, 1909. Ex Herb. J. Egeland, Herb. Mycolog. Lars Romell, Stockholm.

Fructification annual, effused in patches usually extending about 15 cm. long, up to 4 mm. but mostly 2.5 mm. thick; margin narrow, appressed, fimbriate, mostly 0.5 mm. wide or less, often becoming fertile; subiculum less than 0.3 mm., "ivory-yellow"; tubes often oblique, not stratified, with fragile walls, 0.5–4 mm. long; mouths angular, "cream-color," "Naples yellow" to "mustard-yellow," 1–4 mostly 1–3 to a mm.; dissepiments dentate-lacerate, at times becoming somewhat translucent, but not conspicuously so, averaging 78–300 μ thick; basidia 11 $\times$ 3 μ, short-cylindric or allantoid, often 2-guttulate, 3–6 $\times$ 1–1.5 (2) μ, spores hyphae septate, 2–5 μ, soft, fibulate, incrusted, cystidia present, capitate or appearing as ends of projecting incrusted hyphae, averaging 11–22 $\times$ 2–7 μ, heads mostly 5.5 $\times$ 3–4 μ.

Allied species. — This plant is allied to *Polyporus sericeo-mollis*, from which it differs chiefly in color characteristics. The spores are the same. Dried plants of *Pol. flavicans* remain adnate to the substratum — a growth habit which does not always hold for the former species. Of the yellow plants *Pol. flavicans* is more fragile than *Poria xantha*, and differs further in that it has fibulate hyphae and lacerated dissepiments. In some plants, too, there is more of a tendency toward a translucent condition of the margin and where the tubes are bruised than can be found in *Poria xantha*.

Habitat. — *Picea engelmannii*, *Pinus ponderosa*, *Tsuga heterophylla*.

Distribution. — British Columbia, Idaho, Montana.

Occurrence. — This is a rare plant in North America. The name, however, has been used for other species.

Poria aneirina Somm. non Fr. in Sacc., Syll. Fung., 6 : 314. 1888.

Polyporus aneirinus Somm. non Fr. in Romell, Arkiv för Botanik, 11 : 21. 1911.
Polyporus serenus Karst., ex Romell, Arkiv för Botanik, 11 : 21. 1911.

Plate XXXIII, Figure 2

Important specimens:

Boletus macer Somm. on *Populus sp.*, fragment type. Herb. Somm., Herb. Bresadola, Stockholm.

Physisporus serenus on *Populus tremula*, Mustiala, Finland. Ex P. A. Karsten, Herb. Bresadola, Stockholm.

Polyporus aneirinus on *Populus sp.* Blytt's Herb., Riksmuseet, Stockholm.

Polyporus aneirina Somm. on *Populus tremula*, Prenčow. Leg. Andr. Kemet. 1889. *Pol. serenus* Karst., Herb. Bresadola, Stockholm.

Polyporus fulvescens Bres., n. sp., on *Populus tremula*, Andr. Kemet., 1892. Herb. Bresadola, Stockholm.

Polyporus aneirinus on *Populus tremula*, Saltsjö-Duvanäs, 1913. Herb. Mycolog. Lars Romell 12709, Stockholm.

Polyporus aneirinus on *Populus tremula*, Nacka, 1914. Herb. Mycolog. Lars Romell 12710, Stockholm.

Polyporus aneirinus Laubholz, Saltsjö-Duvnäs, 1922. Herb. Mycolog. Lars Romell 12712, Stockholm.

Fructification annual, resupinate, drying somewhat brittle or crisp, and becoming resinous, usually growing on decorticated wood in limited areas up to 1 cm. or more, but mostly in elongated patches 8 mm. or less in length, up to 1 mm. thick, drying to 0.5 mm. or less, usually not cracking upon drying, but occasionally breaking up or away from the substratum in small sections as if eaten by insects or at least becoming somewhat irpiciform in age and in herbarium specimens; margin tomentose, less than 0.5 mm. wide, "pale olive buff," soon becoming fertile; tubes often oblique, not stratified, 0.5–1 mm. and mostly less than 1 mm.; mouths buff drying to "cinnamon-buff" to "tawny," and most frequently seen to be "tawny," angular 1–2 to a mm.; dissepiments becoming irpiciform, thin; basidia 11 × 3–4 μ; spores hyaline, subglobose, angular, 5–6 × 3–4 (5.5 × 4); incrusted pegs 13–18 × 4–8 μ; hyphae incrusted, cross walls occasional, clamp connections present.

Allied species. — Plants which dry to "russet," "ochraceous tawny," "antique-brown," or "cinnamon-brown" and exhibit a "light buff" margin are readily confused with *Pol. resinascens* Romell (Pl. XXXIII, Fig. 1). The spores of *Pol. aneirinus* are mostly

5.5 × 4 μ, whereas those of *Pol. resinascens* are narrow, i.e. 4–5 (7) × 2–2.5 (3) μ (Romell).

Pol. aneirinus Somm. non Fr. may be confused sometimes with *P. sinuosa,* especially old plants. The spores of the former are subglobose; those of *P. sinuosa* are cylindrical or allantoid, 4–6 × 1–2 μ.

Habitat. — *Populus deltoides, P. tremuloides, P. trichocarpa, Salix sp.*

Distribution. — Ontario, Colorado, Idaho, Illinois, Minnesota, Montana, New Mexico, South Dakota, Wyoming.

Poria xantha (Fr.) Lind. forma *crassa*

Poria crassa Karst. non Fr. in European herbaria.

Plate XXXIV; Plate XXXV, Figures 1–2

Important specimens:

Poria crassa Karst., Mustiala, Finland. Leg. P. A. Karsten, 1872. Ex Herb. Karsten, Herb. Mycolog. Lars Romell, Stockholm.

Fructification perennial, broadly effused sometimes for a distance of 1 meter, whitish or yellowish, 3 to 10 mm. thick, often exhibiting checks and cracks in the fruiting structure, becoming friable and distinctly chalky in old dried plants; margin 1 to 2 mm. wide, arachnoid to pubescent, later becoming fertile, "pale olive buff"; subiculum indistinct, fusing with the base of the tubes so as to be indistinct, chalky; tubes indistinctly stratified, frequently as much as four layers, the old layers white and the newer layers white or yellowish, 3 to 8 mostly about 4 mm. long each season; mouths subangular, mostly 4–6 to a mm., "cream-buff" to "chamois"; dissepiments thin, slightly fringed, basidia 9–11 × 5 μ; spores cylindrical, smooth, not strongly curved, often 2-guttate, 4–6 × 1–1.5 μ; no clamp connections observed; hyphae brittle, mostly 2–4 μ in diameter, sometimes incrusted.

Allied species. — This poria belongs to the *P. vulgaris* form series. See discussion presented under *P. lenis.*

Karsten referred thick specimens of his *P. xantha* to *P. crassa.* The limits of the species and the form are arbitrary and might very well be disregarded, but it is believed that this name *crassa* will prove to be a convenient one to use in designating a form which occurs so commonly in the field. Measurements of numerous collections determined by Romell indicate that the specimens of *P. xantha* are almost invariably under 2.5 mm. in thickness, and

none of them are as much as 3 mm. This arbitrary limit is retained for convenience in usage, even though it is held that one is simply a thick form of *P. xantha*. Specimens can be found which show a range in thickness from that "typical" of *P. xantha* to *P. xantha* forma *crassa*.

These old thick forms may be difficult to distinguish from possible resupinate forms of *Fomes officinalis* Fr., which is also very common on standing Douglas fir and western larch, and so often on snags and fire-killed timber in the western forests. The two fungi can readily be separated, however, by their spores. The spores of *F. officinalis* are 3–4 × 4–5 μ, whereas those of *P. xantha* forma *crassa* are allantoid, 3–5 × 1 μ. The poria is usually lemon-yellow when fresh and fades with age, while the pore surface of *F. officinalis* is white when fresh and often becomes yellowish upon drying. Both fungi are bitter to the taste.

Cultures. — Isolated from *Picea glauca;* Igloo, Mt. McKinley National Park, Alaska. The chief features of this fungus in culture are presented in Table I. The colors of mycelium in culture are similar to those produced in the fruiting bodies in nature on wood. An area of appressed growth surrounding the inoculum and bordered by fluffy cottony mycelium is characteristic of this fungus. Pore formation takes place in 37-day-old cultures.

Habitat. — *Larix occidentalis, Picea engelmannii, P. glauca, Pinus contorta, P. echinata, P. lambertiana, P. palustris, P. ponderosa, P. radiata, P. strobus, Pseudotsuga taxifolia, Tsuga mertensiana.*

Distribution. — British Columbia, Alaska, California, Georgia, Idaho, Massachusetts, Michigan, Minnesota, Missouri, Montana, New Mexico, Oregon, Vermont, Washington, Wisconsin.

Occurrence. — Although this plant is found in the region of the Great Lakes and elsewhere in the east, it is most common in the Rocky Mountain region and in the forests of the Northwest. In Alaskan forests I have found that it occurs abundantly. It is common on fire-charred stumps of *Pinus contorta* in the Tongass National Forest, and it is widely spread on burned logs and fallen spruce trunks (often covering several feet of their wood surface) in the open timber types of the interior, especially in the region of Mt. McKinley. It is equally common in the Yukon Territory.

Decay. — In the advanced stages of the decay caused by this fungus the wood becomes a brownish red, and breaks up into cubes that

can readily be crumbled between the fingers. The fungus does not, however, form conspicuous mycelial felts in the cracks of the wood, as in timber decayed by *Fomes officinalis* and *Pol. sulphureus*. The whitish mycelium found in such areas becomes chalky and is never so conspicuous as it is in the wood decayed by these two last-mentioned fungi.

Poria xantha (Fr.) Lind. in Romell, Svensk Botanisk Tidskrift, 20 : 20. 1926

Poria vulgaris var. *luteo-alba* Bres., Kmet., 86.
Poria luteo-alba Karst. in Sacc., 6 : 299. 1888.
Polyporus selecta Karst.? sensu Romell, Arkiv för Botanik, 2 : 25. 1911.
Polyporus flavus Karst.? sensu Romell, Arkiv för Botanik, 2 : 25. 1911.
Polyporus vulgaris var. *calceus* Fr. sensu Romell, Svensk Botanisk Tidskrift, 20 : 21. 1926.

(See Pl. XX of Vol. XV, facing p. 228)

Important specimens:

Physisporus vitellinus Karst. on *Alnus sp.*, Mustiala, Finland. Leg. P. A. Karsten, Herb. Mycolog. Lars Romell, Stockholm.
Physisporus luteoalbus Karst., Mustiala, Finland. Leg. P. A. Karsten, Herb. Mycolog. Lars Romell, Stockholm.
Physisporus calceus (Fr.) var. *flavus-Polyporus selectus* Karst. on pine, Mustiala, Finland. Herb. Bresadola, Stockholm.
Polyporus xanthus Fr. orig. exemp. Fries., Femsjö. Herb. Bresadola, Stockholm.

Fructification annual or perennial, broadly effused up to 60 cm. or more, 1–2.5 mm. usually 1 mm. thick, whitish to sulphureous and at least sulphureous within the pores, sometimes exhibiting checks and cracks in the fruiting structure of the thicker specimens and such plants becoming somewhat friable and chalky in age, separating readily from the substratum when fresh, and in the powdery forms readily crumbling away; margin white, pubescent to arachnoid, 1 mm. wide in young specimens but becoming fertile soon, so that in most collections the pubescent margin is absent; subiculum thin, mostly less than 0.5 mm.; tubes in one layer or often indistinctly stratified, usually not more than three layers in typical plants, 1–2 mm. long; mouths whitish, "pinkish buff," but mostly "ivory yellow," to "Naples yellow" to "colonial-buff," 4–5 to a mm.; dissepiments rather thick; basidia 9–18 × 2.5–6 μ; spores allantoid, 4–6 × 1–1.5 μ, not strongly curved, nonguttate, hyphae undulate, brittle not fibulate, sometimes incrusted, seldom septate, 1–4 mostly 2–4 μ in diameter, no clamp connections.

Allied species. — The yellow *Pol. flavicans*, which is not common in North America, is much more fragile than *P. xantha*. The first species suggests a yellow *Pol. sericeo-mollis* and, in habit of growth, does not grow extensively over the log surfaces.

Remarks. — Collections of Swedish specimens of *P. xantha*, when fresh, are whitish to "ivory-yellow." The color is retained for the most part after drying. In the original specimen (Femsjö, Fries) the mouths are now brown "clay color," rather than yellow, 4–5 to a mm.; tubes up to 1 mm. long. The fragment is too small to examine microscopically, but notes on the packet — probably made by Bresadola — state: spores? 5–6.5 × 4.5–5.5 μ. It is to be observed that these measurements do not fit the description presented here, but since it was apparently doubtful whether the spores belonged to the original specimens in question and since it is impossible to make additional measurements, it is believed that the spores from collections now called *P. xantha* in Sweden (*sensu* Lind.) should be interpreted as belonging to that species.

Physisporus vitellinus Karst. is a somewhat chalky plant, 0.5 mm. thick; mouths 4 to a mm. The characters are those of *P. xantha*.

Habitat. — *Abies balsamea, A. grandis, Chamaecyparis lawsoniana, Larix laricina, L. occidentalis, Picea glauca, P. engelmannii, P. sitchensis, Pinus contorta, P. monticola, P. ponderosa, P. strobus, Pseudotsuga taxifolia, Salix sp., Sequoia sempervirens, Taxodium imbricarium, Thuja plicata, Tsuga canadensis.*

Distribution. — Alberta, British Columbia, Manitoba, Newfoundland, Nova Scotia, Ontario, Alaska, Arizona, California, Idaho, Maine, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New York, North Carolina, Oregon, Pennsylvania, South Carolina, South Dakota, Washington, Wisconsin.

Occurrence. — *Poria xantha* is found frequently on charred logs and stumps on burned-over areas. It is especially common in the northern forests and in the western and northwestern forest regions.

Decay. — Brown cubical rot.

Importance. — In a survey of eighty Canadian paper mills *Poria xantha* was found to be one of the three species of fungi which attack mill roofs. Blair (5) reports: "There is no evidence that other species of fungi than those mentioned . . . in connection with cotton mill roofs, *Lentinus tigrinus, Lenzites trabea*, and *Poria xantha*, cause these losses." When the roof of a paper mill is

built of wood, the moisture in the air permits the development of the fungi. It is reported that rapid rotting takes place and that it is often necessary to renew the timber after six or eight years' service. Moisture enters the spaces between the planks and reaches their upper side, where it condenses and causes a moist condition of the planks during prolonged periods.

The use of wood which resists decay, ventilation which carries away the moisture, liberal dry-air heating, and a heat-insulating layer placed on the upper side of the planks are suggested as remedies.

Twenty-four weave-shed roofs of cotton mills, nearly all in New England, were also found to be badly decayed and, apparently, from the same cause (4).[3] Of this lot, in only two (which made less than one per cent of the total area) was it found that trouble was not beginning to show in less than six or eight years. Referring to the prevention of this decay, the author states that a safe roof can be made of two thicknesses of plank separated by three layers of tarred paper. The inner plank is of high grade material, while the outer one is of inferior wood, mostly sapwood, which has received preservative treatment. A tar-and-gravel finish is then put on.

Poria ambigua Bres., Atti Accad. Rovereto, III, 3 : 84. 1897

(See Pls. XVII and XVIII, Fig. 1, of Vol. XV, facing p. 228)

Important specimens:

Polyporus (*Poria*) *ambigua* Bres., n. sp., on Robinia. Leg. Bresadola, 1894. Herb. Bresadola, Stockholm.

Poria ambigua Bres. forma., Linwood, Ohio. C. G. Lloyd. Herb. Bresadola, Stockholm.

Fructification annual, effused in patches up to four or five meters long, on logs and stumps — usually on the top and the sides of the wood, a habit which is conspicuously different from that of most of the porias — inseparable, up to 10 mm. thick, snow-white when fresh and remaining white or dirty white, "cartridge-buff" or "cinnamon-buff" in herbarium specimens; margin pubescent, white, or "ivory-yellow," sterile, 1 to 2.5 mm. wide, often dis-

[3] *Fomes officinalis* is mentioned, but according to the author's second account one year later this fungus was apparently confused with *P. xantha*. See comments under "allied species" in the discussion of *P. xantha* forma *crassa*.

appearing in age; subiculum inconspicuous, 0.3–1 mm., white, concolorous with the tubes; tubes 2–5 mm. long, unstratified, sometimes appearing as conical structures; mouths angular, thin walls, dissepiments finely fringed, averaging 1-3 per mm., basidia 11–18 (40) × 4-7 μ, 4-spored; spores produced abundantly in almost all stages of development, and can be seen to be abundant even in old specimens in the herbarium, obovate, ellipsoidal or oblong, 4–6 × 3–3.5 μ; cystidia not present or inconspicuous in most plants, but rarely crystalline-capitate cystidia are found, sometimes measuring 10–18 × 4–8 μ; tramal hyphae simple or branched, very wide and thin-walled, 3–6 and mostly 3–4 μ in diameter, cross walls occasional.

Allied species. — Old long-tubed specimens of *P. corticola* sometimes dry so as to suggest *P. ambigua.* This "state" of this plant is seldom found in North America, but it is not uncommon to find it in northern Europe. The conspicuous cystidia of *P. corticola* separate it from *P. ambigua.*

Young specimens of *P. ambigua* may also suggest *P. semitincta.* The short tubes of *P. semitincta*, usually not more than 0.5 mm. long, and the short-cylindric spores of that species readily separate it from *P. ambigua.*

Irpex tulipifera in the resupinate state resembles *P. ambigua* somewhat. The abundance of spores to be found in *P. ambigua* and the absence of conspicuous incrusted cystidia in *Irpex tulipifera* are features of diagnostic value used to separate the two when the latter fungus is found in a resupinate condition.

Remarks. — Specimens in the herbarium are exceedingly liable to be attacked by insects, and special care is required to keep one's collection of this species from being destroyed.

Habitat. — *Acacia baileyana, A. longifolia, Acer rubrum, Amelanchier canadensis, Betula lutea, Celtis occidentalis, C. reticulata, Fagus grandifolia, Fraxinus nigra, Gleditsia triacanthos, Hicoria ovata, Juglans nigra, Liquidambar styraciflua, Nyssa aquatica, N. diflora, Magnolia virginiana, Populus grandidentata, Plumbago sp., Ligustrum sp., Pyrus malus, Quercus alba, Q. bicolor, Q. imbricaria, Q. michauxii, Q. nigra, Robinia pseudo-acacia, Saccharum officinarum, Salix nigra, Solanum triquetrum, Ulmus americana, Umbellularia californica.*

Distribution. — Nova Scotia, Alabama, Arkansas, California, District

of Columbia, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Missouri, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, Texas, Virginia, Washington, West Virginia.

Occurrence. — Common throughout hardwood forests, and especially in bottom lands subject to overflow. This poria is the most common polypore to be found on the logs, snags, and dead, standing bottom-land timbers throughout the Mississippi River flood lands. It is nearly certain to be found in almost any of the swamps of the South from Florida westward. It appears abundantly on fire-injured or -killed elm, maple, and black ash, within two to three years after the death of the trees, even though it may seldom occur in such a type before the forest fire.

Importance. — On superficial examination this plant might be mistaken, according to Fawcett and Lee, for the cottony rot fungus of citrus trees, *Sclerotinea libertiana* (7). It has been observed abundantly on the roots of citrus trees growing in the so-called dry-bog soils of Tulare County, California. It is said to be found there in situations where the soil tends to be waterlogged at times. The fungus, however, is believed to be secondary in nature. It breaks down and rots the bark and wood of the roots after they have been killed by waterlogging or injured by other organisms.

The fungus forms a white, smooth, feltlike coating over the surface of the dead parts of the roots and may also extend over the surface of the live parts without penetrating the bark. "It may also form on the surface of stones or sticks in the soil. Portions of the root that have been dead for some time are more or less pithy, but not soft or punky, showing a dry white rot."

Specimens of this fungus labeled "*P. vaporaria*" have been determined by me to be *P. ambigua*. Cultures of the plant from California are identical with those of *P. ambigua* isolated from *Nyssa biflora*, from Stark, Florida. The characteristic tube-forming habit of "*Poria vaporaria* Fr. sensu Burt" as illustrated in Plate XXIII of Paper III of this series is a similar striking feature of the plant from Florida. Morphologically, this "*P. vaporaria* Fr. sensu Burt" is totally different from the true *P. vaporaria* as interpreted in Sweden and in this series of papers.

It is of special interest that the California plant is found on roots injured by too much water, especially in the dry-bog soils

of the San Joaquin Valley. On tree snags, logs, and roots found on lowland and land subject to overflow *P. ambigua* is common in the south and southeastern forest districts. Here it occurs chiefly on slash timbers.

Trametes heteromorpha (Fr.) Bres. in Neuman, Wis. Geol. and Nat. Hist. Surv., p. 40. Scientific Series, Bull. 23, No. 10. 1914

Daedalea heteromorpha Fries, Obs. Myc., 1 : 108. 1815.
Lenzites heteromorpha Fries, Epicr. Myc., p. 407. 1838.
Coriolellus sepium (Berk.) Murr., Bull. Torr. Bot. Club, 32 : 481. 1905. Pro parte.
Coriolus hexagoniformis Murr., North Am. Fl., 9 : 20. 1907.
Trametes laceratus Lloyd, Mycol. Notes, 4 : 604. 1916.
Trametes heteromorpha (Fr.) Lloyd, Mycol. Notes, 5 : 848, f. 1416–1419. 1919.
Trametes hexagoniformis Murr. In American literature.

Plates XXXVI–XXXVII

Important specimen:
Trametes heteromorpha (Fr.) Bres., Herb. Bresadola, Stockholm.

Fructification perennial, coriaceous, resupinate or effused-reflexed, 0.2–3 × 1–35 × 0.1–1 cm.; surface tomentose often becoming nearly glabrous, white, "cream-buff," often forming tubes on upper surface of partly formed pilei; margin obtuse, undulating, tomentose, concolorous; margin of resupinate plants less than 0.3 mm., tomentose but soon becoming fertile; context white and concolorous with the tubes, up to 1 mm. thick, homogeneous; tubes mostly white, sometimes "cream-buff," 1.5–15 mm. long; mouths angular, daedaloid to irpiciform, 0.5–3 mostly 1–2 to a mm.; dissepiments lacerate, rather thick; basidia hyaline, almost or fully half as broad as they are long, 13–15 × 8–10 μ, 2–4-spored; spores smooth, hyaline, cylindric-ellipsoid, apiculate, 8–15 × 3.5–4.5 (5.5) μ, tramal hyphae hyaline, branched, smooth, or incrusted, 3–4 μ in diameter; no cystidia.

Allied species. — *T. heteromorpha* differs from *T. variiformis*, a closely related species, in its large pores and white or yellowish white pileus.

P. subsinuosus might suggest *P. sinuosus* because of the name, but it is actually most closely allied to *T. heteromorpha*. *T. subsinuosus* and *T. heteromorpha* differ only because of the smaller spores in the former and because *T. subsinuosus* never possesses lamellae. The spores of *P. subsinuosus* are not at all similar to those of *P. sinuosa*.

The brown pileus of *T. serialis* is ordinarily used to separate this plant from *T. heteromorpha.*

Habitat. — *Abies balsamea, A. grandis, Juniperus virginiana, Larix occidentalis, L. laricina, Picea glauca, P. engelmannii, P. rubra, P. sitchensis, Pinus contorta, P. monticola, P. ponderosa, Pseudotsuga taxifolia, Tsuga canadensis, T. heterophylla, T. mertensiana.*

Distribution. — Alberta, British Columbia, Nova Scotia, Yukon Territory, Alaska, California, Colorado, Idaho, Michigan, Minnesota, Missouri, Montana, New Hampshire, New York, Oregon, Pennsylvania, South Dakota, Vermont, Virginia, Washington, Wisconsin.

Occurrence. — *T. heteromorpha* occurs much more frequently in the northwestern forests of North America than in northern Europe, where it was studied by Fries. I have collected it abundantly in the Northwest and have found it frequently in parts of the Yukon Territory and in Alaska, especially in the forests of the Kenai Peninsula. It is not a common plant in Sweden. Near Uppsala, for example, the fungus has been found in only one or two forest localities.

Importance. — *T. heteromorpha* is found on railroad ties and other structural timbers. It produces decay in buildings and frequently causes damage so serious as to necessitate a complete replacement of the wood. The foundation timbers of the bank building in Valdez, Alaska, decayed by *T. heteromorpha*, are illustrated in Plate XXXVII.

Polyporus sericeo-mollis Romell, Hymen. Lapp., Arkiv för Botanik, 11 : 22. 1911

Leptoporus sericeo-mollis (Rom.) Bourd. & Galz., Hymen. Fr., p. 548. 1927.

Plate XXXVIII

Important specimens:

Polyporus sericeo-mollis Romell, Lidingö, 1908. Herb. Mycolog. Lars Romell, 12614, Stockholm.

Polyporus sericeo-mollis Romell, Nattavara, 1910. Herb. Mycolog. Lars Romell, Stockholm.

Polyporus sericeo-mollis Romell, Femsjö, 1911. Herb. Mycolog. Lars Romell, 12616, Stockholm.

Fructification annual, white, soft, fragile, and crumbling in dried plants, effused for 10 cm., mostly resupinate, the margins of the plant sometimes reflexed so as to form a narrow pileus, the edge of

which is in turn reflexed inward, up to 6 mm. or more thick, but mostly 2–2.5 mm.; margin in resupinate plants shows white, 1 mm. wide, at first pubescent, becoming fertile; subiculum white, thin, less than 0.5 mm.; tubes seldom stratified, 1–3 mm. long; mouths snow-white and mostly remaining so even in dried plants, but occasionally drying to "pale olive buff," 3–4 mostly 3 to a mm., angular, dissepiments thin; basidia hyaline, 4-spored, 14–35 × 5 μ; spores hyaline, 1-guttulate, subcylindric or suballantoid 3–5 (6) × 1–2 μ, hyphae 1–4, mostly 3 μ wide, septate, clamp connections present; no cystidia observed.

Ptychogaster sp. with subglobose or ellipsoidal, often angular, 1-guttulate, conidia (chlamydospores), 5.5–7 (8) × 3–4 (5) μ occur in masses in mounts made from freshly collected material that accompanies *Polyporus sericeo-mollis*. I have collected this Ptychogaster, which is in common association with the Polyporus about Uppsala, where plants are to be found on old fence rails. Donk (6) suggests either that *P. sericeo-mollis*, with its chlamydospore forms, might prove to be the same plant, or that "*Tyromyces Ptychogaster* (*Polyporus Ptychogaster*)" may be considered a separate species. This subject, he points out, should be investigated.

Allied species. — At times this plant might be mistaken for *Poria lenis*, which feels soft and velvety to the touch and remains in this condition even in herbarium material. *Pol. sericeo-mollis* is also soft, but it tends to crumble in the dried state. The strong curvature of the spores in *P. lenis* is a distinguishing character of that plant.

The pale yellow color of *P. flavicans* separates this soft and fragile species from *Pol. sericeo-mollis*. Also compare *P. cinerascens*.

Remarks. — It is evident that *Pol. destructor*, as interpreted in the Bresadola herbarium at Stockholm, is the same plant. Romell himself (11) states: "As to Fries he has an unpublished picture, which is taken from von Post's work, and this may be either *Pol. sericeo-mollis* or a species which I now call *Pol. subsericeo-mollis*. I think that Schrader, if he had meant *Pol. sericeo-mollis*, which is mostly resupinate and *sericeo-tomentosus*, would not have placed his fungus at the beginning of the section 'Acaules' and described it 'superficie rugosa glabra.'"

Habitat. — *Abies balsamea, Juniperus virginiana, Tsuga canadensis.*
Distribution. — Florida, Michigan, Oregon, Wisconsin.
Occurrence. — This plant seems to occur much more rarely in North America than in Sweden. It is very common on old coniferous fence rails in central Sweden.

Trametes variiformis Pk., Bull. New York State Mus., 28 : 220. 1899

Polyporus variiformis Pk., Ann. Rep. New York State Mus., 42 : 26. 1889.
Polyporus variiformis nodulosus Pk. ex Lowe, New York State College of Forestry, 6 : 93. 1934.
Polyporus variiformis resupinatus Pk. ex Lowe, New York State College of Forestry, 6 : 93. 1934.
Coriolellus serialis (Fr.) Murr. North Am. Fl. 9 : 29, 1907. Pro parte.

Plate XXXIX

Fructification perennial, or at least capable of reviving upon restoration of growing conditions, coriaceous, effused-reflexed or entirely resupinate; pileus 0.1–1 × 0.2–0.6 × 1–7 cm. long, surface hirsute, zonate, blackish, i.e. "deep mouse-gray" at the point of attachment to the substratum, to "cinnamon-buff" near the margin; margin undulating, hirsute, whitish to "cinnamon-buff," fertile underneath; resupinate specimens — margin whitish to "pale drab gray," pubescent, 0.5 mm., becoming fertile; context less than 0.5 to 3 mm., and usually less than 1 mm., with the tubes in resupinate specimens, but of two layers — the upper layer blackish or brownish and of the color of the pileus in pileate plants, and the lower layer concolorous with the tubes; tubes 1–6 mm., usually not more than 3 mm. long in resupinate plants, often opened laterally, "pale pinkish buff" to "avellaneous"; mouths similar in color to that of the tubes, 1–2 mostly 1 to a mm., angular, daedaloid, to irpiciform; dissepiments becoming lacerate, thick, basidia 12–24 × 6–8 μ; spores hyaline, 9–11 × 2–4 μ; hyphae rarely branched, incrusted, apparently nonseptate, mostly 3–4 μ in diameter, no clamp connections, no cystidia.

Allied species. — *T. variiformis* is closely allied to *T. heteromorpha* (Fr.) Bres. When these plants are collected in the more or less resupinate stages, careful examination of all the available material must be made in the field for indications or reflexed portions. The color should be noted at the time, and it is especially necessary

to look for traces of brownish marginal portions or sections which are beginning to turn brown.

The pileus of *T. heteromorpha* is white to whitish yellow; that of *T. variiformis* is brown to blackish. The size of the pores and the hymenial characters are similar for the two plants.

T. variiformis is to be separated from *T. serialis* on the basis of pore characters. The pores are usually larger in *T. variiformis*, namely, 1–2 to a mm.; in *T. serialis* they are 2–3 to a mm.

Habitat. — *Abies balsamea, Betula occidentalis, Fagus grandifolia, Hamamelis virginiana, Larix laricina, L. occidentalis, Picea canadensis, P. engelmannii, P. mariana, P. rubens, P. sitchensis, Pinus contorta, P. strobus, Tsuga canadensis, T. heterophylla, T. mertensiana.*

Distribution. — Alberta, Newfoundland, Ontario, Yukon Territory, Alaska, Arizona, Colorado, Michigan, Montana, New Hampshire, New York, Pennsylvania, Vermont, Virginia, Washington, Wisconsin.

Occurrence. — Although *T. heteromorpha* occurs abundantly in certain localities, *T. variiformis* is more commonly found than *T. heteromorpha*. This close relative of *T. heteromorpha* is not found in Sweden.

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LITERATURE CITED

1. Baxter, D. V. 1932. Some Resupinate Polypores from the Region of the Great Lakes. III. Pap. Mich. Acad. Sci., Arts and Letters, 15 (1931): 191–228.

2. —— 1933. Some Resupinate Polypores from the Region of the Great Lakes. IV. *Ibid.*, 17 (1932): 421–439.

3. —— 1934. Some Resupinate Polypores from the Region of the Great Lakes. V. *Ibid.*, 19 (1933): 305–332.

4. Blair, R. J. 1919. Fungi Which Decay Weave Shed Roofs. Phytopathology, 9: 54.

5. —— 1920. Wood-destroying Fungi in Pulp and Paper Mill Roofs. *Ibid.* 10: 61.

6. Donk, M. A. 1933. Revision der Niederlandischen Homobasidiomycetae-Aphyllophoraceae II. Mededeelingen van Het Botanisch Museum en Herbarium Van DeRijks Universiteit Te Utrecht. No. 9, 1–278.

7. Fawcett, H. S., and Lee, H. A. 1926. Citrus Diseases and Their Control, pp. 5–582. New York.

8. Humphrey, C. J., and Siggers, P. V. 1934. Temperature Relations of Wood-destroying Fungi. Journ. Agric. Res., 47 (1933) : 997–1008.

9. Markwardt, L. J. 1931. The Distribution and the Mechanical Properties of Alaska Woods. Tech. Bull. 226, U. S. Dept. Agric., pp. 1–80.

10. Overholts, L. O. 1929. Mycological Notes for 1926–27. Mycologia, 21 : 274–287.

11. Romell, Lars. 1926. Remarks on Some Species of Polypores. Svensk Botanisk Tidskrift, 20, Heft 1 : 1–24.

12. Weiss, H. F. 1916. The Preservation of Structural Timber, pp. 1–361.

PLATES XXX–XXXIX

PLATE XXX

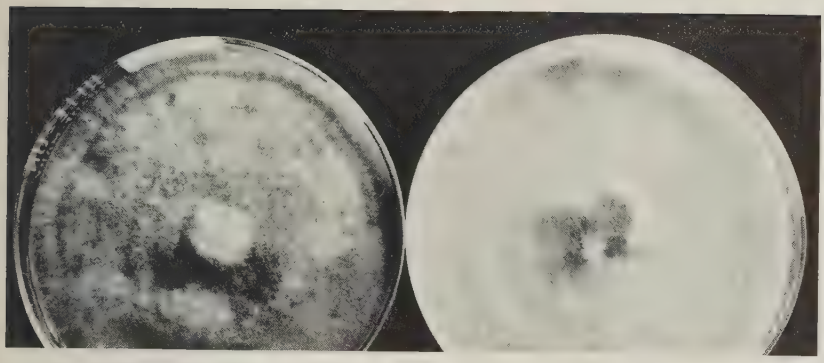


FIG. 1. *Poria Weirii*

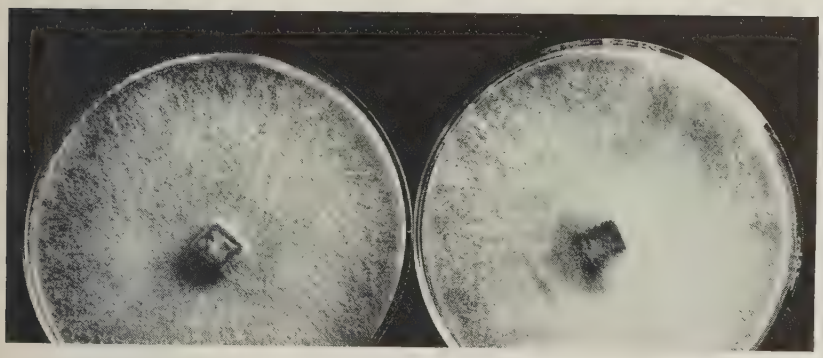


FIG. 2. *Poria mutans* var. *tenuis*

FIG. 3. *Poria pereffusa*
Resupinate polypores cultured in the dark and in the light (cultures two weeks old)

PLATE XXXI

Poria lenis Karst. on *Chamaecyparis nootkatensis*, Sitka, Alaska

PLATE XXXII

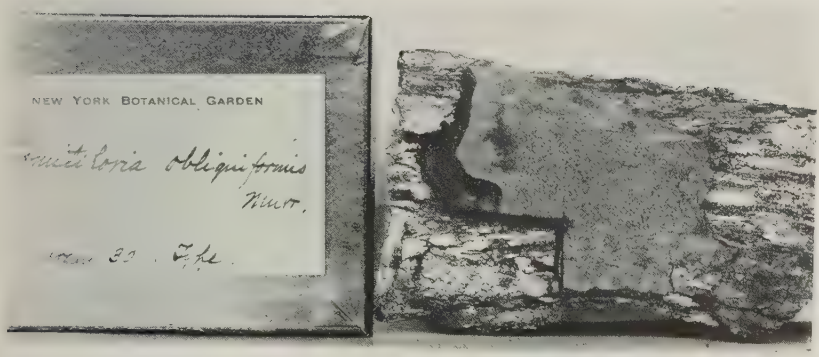


FIG. 1. *Poria punctata* Fr. (= *Fomitiporia obliquiformis* Murr.) New York Botanical Garden

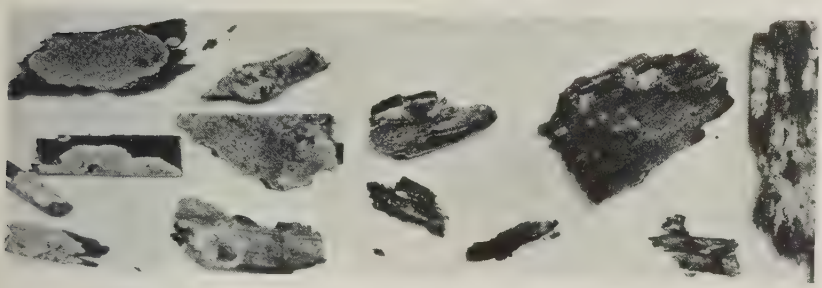


FIG. 2. *Polyporus* (*Poria*) *flavicans* Karst., det. Romell (*Poria crassa* Karst., det. Bresadola) on spruce. Leg. J. Egeland. Riksmuseet Naturhistoriska, Stockholm, Sweden

PLATE XXXIII

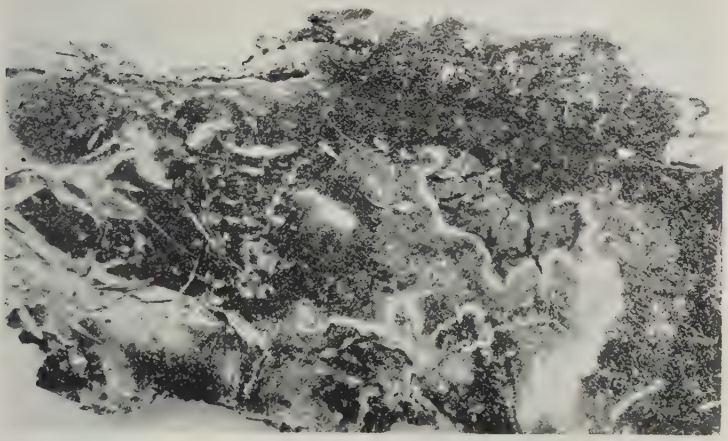


FIG. 1. *Polyporus resinascens* Romell, det. Romell, on *Populus tremula*. Herb. Mycolog. Lars Romell, Stockholm, Sweden

FIG. 2. *Poria aneirina* Somm. non Fr. on *Populos tremula*. Herb. Mycolog. Lars Romell, Stockholm, Sweden

PLATE XXXIV

Poria xantha forma *crassa* on *Pinus contorta*, Skagway, Alaska

PLATE XXXV

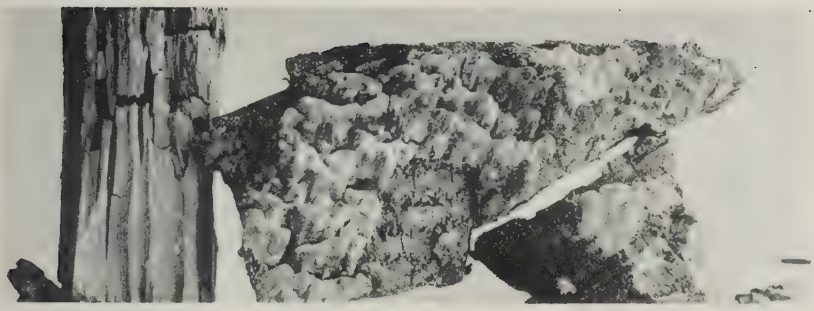


FIG. 1. *Poria xantha* forma *crassa* on *Pseudotsuga taxifolia*. Vancouver, British Columbia

FIG. 2. *Poria xantha* forma *crassa* on *Picea glauca*. Igloo, Mt. McKinley National Park, Alaska

Trametes heteromorpha (Fr.) Bres. on *Tsuga mertensiana*. Ptarmigan Lake, vicinity of Moose Pass, Alaska

Teredo navalis on foundation timbers removed from a bank building, Valdez, Alaska

PLATE XXXVIII

Polyporus sericeo-mollis with *Ptychogaster sp.* Hälltorpet, vicinity of Uppsala, Sweden

Trametes variiformis Pk. on *Picea glauca*. Carcross, Yukon Territory

A FOREST SOIL STUDY OF THE UNIVERSITY OF MICHIGAN BIOLOGICAL TRACT

ROY L. DONAHUE

THE University of Michigan Biological Station tract lies in the central-western part of Cheboygan County between Burt and Douglas lakes (see Map 3).[1] Within its 3,910 acres is found a variety of natural conditions that readily lend themselves to a related study of forestry and soils.

The tract is characterized by a predominance of pine land that was logged in 1871–72. Repeated fires have destroyed nearly all remnants of the original stand, leaving large-toothed aspen, red oak, red maple, and pin cherry as the present forest cover.[2] In smaller bodies virgin hardwoods occupied the land to the exclusion of pines. After the logging of the original hardwoods in 1912 the fires that followed were almost as intense and numerous as on the pine land. Less permanent damage by fire was done, however, as is evidenced by the fact that the present cover on the hardwood land is almost identical in composition with that of the original growth, although the productivity may have been somewhat decreased by this burning. Swamp land, which is confined primarily to the area lying just to the north of Burt Lake, supports an abundance of white cedar and black spruce.

Profile features of the well-drained soils show (*a*) coarse organic matter on the surface, then (*b*) a leached (eluviated) gray layer over (*c*) a concentrated (illuviated) horizon, yellow brown to brown, overlying (*d*) parent material, usually of a sandy texture. This succession of layers indicates that the soils of the area belong to the Podzol Soil Region. The swamp soils are, in the main, dark brown to black, well decomposed, neutral to slightly acid in reaction, and underlain with white saturated sand at a depth of from three to five feet. The

[1] The Biological Station tract is located in Townships 36–37 North, Range 3 West.

[2] See the Appendix for the scientific names of all species mentioned.

Map 3. Sketch map of Michigan showing the location of the University of Michigan Biological Station

soil profile of the small ericaceous (muskeg) bogs that from a forestry standpoint are nonproductive exhibits a coarse, permanently wet, yellow peat in which the individual plant residues may be identified even to a depth of several feet.

The late Dr. J. W. Toumey (5) stated that, though climate is the most important influence in determining the range of a forest species, the character and the condition of the soil are often responsible for the limitation of that species. Also he wrote that the influence of the soils is most apparent in the local distribution of trees.

Many attempts have been made to explain the occurrence and the form of vegetation without mention of the soil, and other works have sought to magnify pedology as the key to all life distribution. Probably greater truth may be found by a joint study of forests and soils, not in the sense of cause and effect particularly, but rather in the sense of their reciprocal relationships. Such a combined study has been given impetus recently by Professor J. O. Veatch (6–7) and by Professor R. H. Westveld (9).

A discussion of the simultaneous occurrence of forests and soils on the Biological Station tract is here attempted, by way of observations on the kind of virgin cover (Map 4), the present greater vegetation, and brief notes on silvicultural practices that are intimately related to the character of the soil.[3]

A warning is sounded by Sampson (4) as to the use of the soil type as a basis for mapping vegetation types: "Biotic competition, rate of succession, habitat range, preoccupation by approximately ecological equivalents, biotic history, topographic and climatic factors may frequently be paramount over the differences in soil characteristics selected by the U. S. Bureau of Soils to delimit soil types." This observation discourages any attempt to correlate forests and soils. But in this study, with the soils mapped on a larger scale (5 inches = 1 mile) and in greater detail than specified by the U. S. Bureau of Chemistry and Soils, a much closer relationship is more likely to exist. Also, in this paper several soil types with closely related characteristics are grouped to facilitate their study. These special treatments bring about a detail in relationship that is not possible with the use of standard soil maps.[4]

For convenience of presentation the soil types are grouped on the basis of their original forest cover, such as: pine land, hardwood land, conifer-hardwood land, and swamp land.[5]

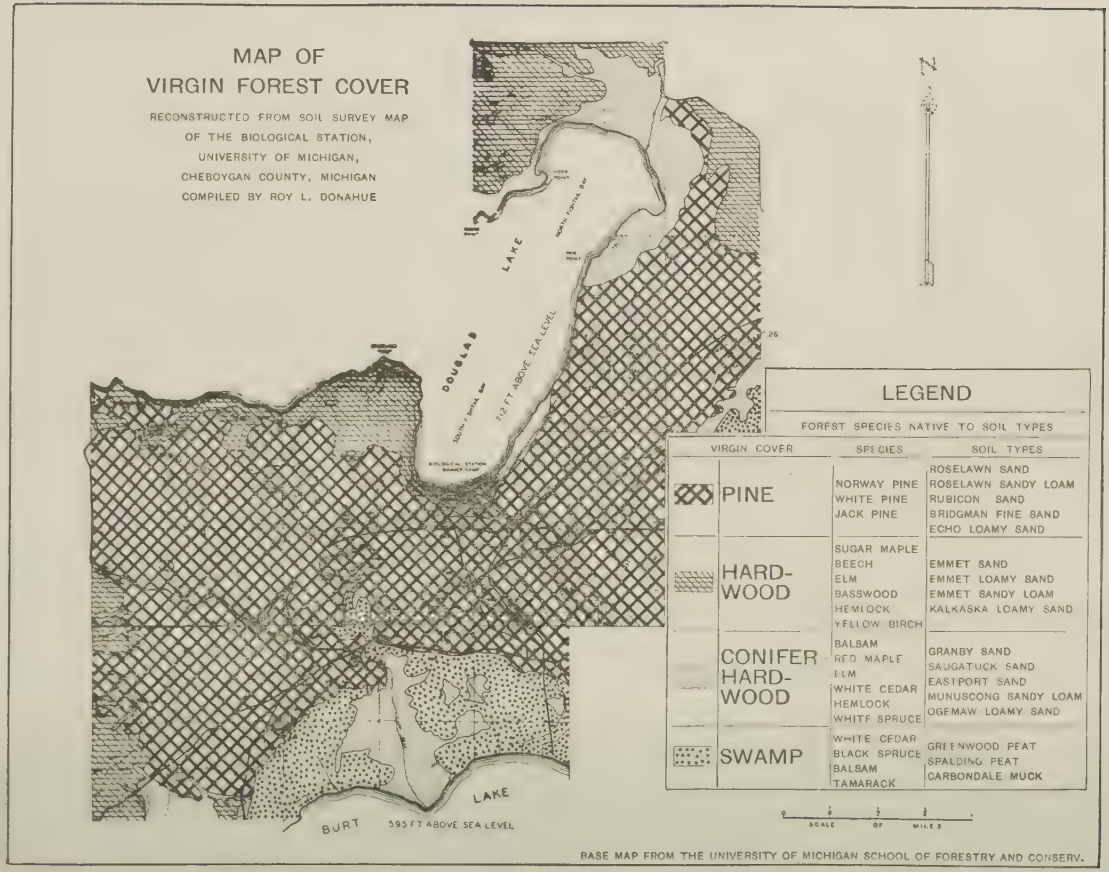
PINE LAND

Sixty-nine per cent of the tract is classified as land that originally supported mainly Norway pine and white pine, with a sparse mixture of red oak, and an occasional hemlock and jack pine. Clear-

[3] For a discussion on the general subject of forests and soils see reference 2; and for a specific study of soil characteristics and forest growth see Westveld (9).

[4] For a description of the soil types encountered see Veatch (8).

[5] This classification scheme corresponds very closely to the system presented by Dr. Frank C. Gates (1), namely, Bog, Picea-Abies, Pine, and Beech–Maple.



MAP 4. The virgin forest cover as reconstructed from a detailed soil survey, supplemented with

cutting and severe subsequent fires have combined to prevent the natural regeneration of the valuable pines on all except a few acres on the area.

Lack of uniformity in the present forest cover appears to be directly related to the frequency and intensity of fires, and to slight differences in soil textures. The cover on the loamier pine soils is similar in composition to that found on the more sandy soils, but differs in the more luxuriant and thrifty character of the former, owing to the presence of more silt and clay in the surface as well as to the existence of sandy clay lenses in the substratum (Pl. XL, Fig. 2). Repeated fires have exhausted the fertility of some areas to the point where they now support stunted oak sprouts (sometimes 15 or 20 to the stump), with few or no associated forest species, and seldom any ground cover save reindeer moss (lichen). On such places a high mortality of pine seedlings may be expected. By far the greater part of the pine land is covered with an abundance of large-toothed aspen, red maple, red oak, pin cherry, and an occasional trembling aspen (Pl. XL, Fig. 1). I am told by Professor Gates that, if left undisturbed after a damaging fire, pine land will again be dominated by species of the original stand in about 30 to 35 years, provided, of course, that adequate seed trees are present.

Any silvicultural practice on pine land should take cognizance of the fact that soil moisture is likely to be deficient, so that any treatment that tends to conserve this moisture will bring favorable results. Tree roots concentrate in the B layer (Pl. XL, Fig. 3). Below this layer is sandy material that is usually drier than the layer above, which encourages a fibrous feeder-root system at shallow depths, although in addition pines may develop a taproot.

The abundance of large-toothed aspen naturally calls to the forester's mind a possible utilization of this species for a continuous pulp or excelsior stand. Intensive examinations of the growth of aspens have brought to the foreground the information that the life of large-toothed aspen and trembling aspen on pine land seldom exceeds 35 years, with a maximum diameter of six inches (3). This fact, coupled with the usual inability of aspens to maintain themselves in a closed stand for more than about two generations, indicates that the successful management of an aspen stand is very doubtful.

Except in an experimental way only Norway pine, white pine,

or jack pine should be artificially reëstablished on the pine land, if a continuous forest crop is to be expected.

HARDWOOD LAND

Soils grouped to form the pine land represented in Map 4 are, as a rule, yellow to yellow-brown in the B layer (Pl. XL, Fig. 3); those that make up the hardwood land (13 per cent of the tract) are dark brown (Pl. XLI, Fig. 3). An interesting possible explanation of this relationship may be seen in Plate XLI, Figure 2. Here is shown, at a depth of four feet, the substratum of a pine soil containing a limestone fragment that has turned the otherwise yellow sand into a dark umber brown. Thus the parent material of hardwood soils may have had a greater amount of limestone than the parent material of the pine soils.

Quantitative records of the difference in composition between the virgin and the present hardwood forest cover (Pl. XLI, Fig. 1) reveal the following conditions:

TABLE I

THE COMPOSITION OF A TYPICAL MAPLE-BEECH FOREST BEFORE AND AFTER LOGGING (10)

Forest species	Percentage of virgin stand	Percentage of second-growth stand
Sugar maple	35.9	67.3
American beech	21.2	6.8
Hemlock	14.6	2.7
Yellow birch	4.1	0.9
Red maple	3.7	1.7
American elm	2.9	1.5
Basswood	2.1	0.6
White pine	1.5	0.0
White birch	1.4	4.0
White ash	0.8	0.0
Red oak	0.7	0.0

It can readily be seen from the table that sugar maple is the only important forest tree that increases in abundance after the logging of the original stand. According to Professor Gates, this may be due to three things: (*a*) the stumps sprout rapidly after a fire; (*b*) the leaves are distasteful and mildly poisonous to livestock, owing to the presence of an alkaloid known as acerin; (*c*) the

seedlings are tolerant and therefore able to establish themselves very readily under a closed canopy.

When the soils that comprise the hardwood land are a sandy loam, with sandy clay at shallow depths (Pl. XLI, Fig. 3), a denser and faster-growing stand of trees is associated. Soils of the sandier group support a less dense stand and tend to be more cemented into a hardpan, especially on ridge-tops or dry benches, where the profile is not kept young by geological erosion. When a continuous hardpan is present, wind throw is more likely to occur, thus making it necessary on such areas either to clear-cut or to use a light selective method of harvesting the timber.

In a conversation with Professor Gates I learned that, when a few seed trees remain, the length of time required for species of the original hardwoods to dominate hardwood land after a fire is about 20 to 25 years.

Artificial regeneration is seldom necessary on this type of land, owing to the rapid sprouting and natural seeding of the native hardwoods. But where valuable forest trees are absent, only the adapted hardwoods should be selected for planting. The establishing of Norway pine, white pine, white spruce, Norway spruce, and white cedar plantations on hardwood land is a questionable silvicultural practice because of the severe competition afforded by the former hardwoods.

CONIFER-HARDWOOD LAND

About 10 per cent of the tract is shown on Map 4 as a mixture of swamp conifers and lowland hardwoods. In virgin stands this land supported a very heterogeneous mixture and dense growth of balsam fir, American elm, white cedar, yellow birch, hemlock, and white spruce in varying proportions, along with red maple, white pine, black spruce, and black ash. Under present conditions the cover (Pl. XLII, Fig. 1) may contain, in addition to any one or all of the original species, a large percentage of white birch and trembling aspen. It is on this type of land that the trembling aspen grows up to 70 feet in height and attains a diameter of more than 13 inches and makes the harvesting of a stand for pulp or excelsior much more profitable than on the pine land where smaller trees are encountered. Even here, though, one or two crops are all that may be expected when fires are excluded.

Professor Gates states that 15 or 20 years after a fire these soils will be covered with a heavy stand of trembling aspen and white birch, with an understory of balsam fir, white spruce, and hemlock gradually dominating.

Soils of the conifer-hardwood land may be conveniently divided into (*a*) those that possess a brown layer, ofttimes cemented (Pl. XLII, Fig. 3), and (*b*) those that have no brown in the profile (Pl. XLII, Fig. 2). A slightly better drainage may exist in the former group, but both types are classed as poorly drained soils.

Because of a high water table or a hardpan in these soils, wind throw tends to be a serious factor in forest management. A wide variety of forest trees may be planted or managed, owing to the intermediate position of the soils in regard to their natural moisture content. On a few areas in the tract white spruce and white cedar have already been planted and have shown very high survival, as opposed to a poor survival on many of the soils of the pine land, where moisture is deficient.

SWAMP LAND

As shown on Map 4, about 8 per cent of the tract is swamp land. With the exception of a few ericaceous bogs throughout the area, the major part of the organic soils support a jungle-like stand of white cedar, black spruce, balsam fir, tamarack, and a small amount of black ash (Pl. XLII, Fig. 4). Disturbance by man has not destroyed remnants of the virgin timber stand, so that the present growth indicates almost identical composition with that of the former forest.

Alder seeds in rapidly and grows densely on any area where the severe root competition has been decreased through either fire or logging, although, according to Professor Gates, in approximately 10 years the species of the former vegetation will again dominate the site.

Even in closed stands a high wind velocity does serious damage by blowing over these shallow rooted trees. A clear-cutting or a light selection cutting is necessary so as to minimize wind injury.

With only a small amount of expense one can maintain white cedar and black spruce in a productive condition on most of the swamp land because the soil is black, highly decomposed, fertile, and well supplied with moisture.

SUMMARY

1. The University of Michigan Biological Station tract comprises 3,910 acres on Douglas Lake, in central-western Cheboygan County, Michigan.

2. A study of the coexistence of forests and soils is here attempted.

3. The former forest cover may be divided into pines, hardwoods, a mixture of lowland conifers and hardwoods, and swamp conifers.

4. Soils of the area belong to the Podzol Soil Region.

5. After a fire the length of time required for the species of the virgin stand to dominate the cover again is as follows: pine land, 30 to 35 years; hardwood land, 20 to 25 years; conifer–hardwood land, 15 to 20 years; and swamp land, 10 years.

6. A high water table or a hardpan prevents deep root penetration, and thereby induces wind throw.

7. Aspen stand management on pine land is questionable because of the scrubby tree growth, but on conifer–hardwood land shows promise of success, owing to the more rapid growth and the greater ultimate size of the trees.

8. An explanation of the primary difference between a pine soil and a hardwood soil is suggested. This difference may be due to a greater abundance of limestone in the parent material of the hardwood land.

ACKNOWLEDGMENTS

The author is grateful to Dr. Frank C. Gates, professor of botany at Kansas State College, for his suggestions pertaining to the main forest soil problems on the tract; to Dr. C. E. Millar, professor of soils at Michigan State College, for his encouragement of the paper; and to Mr. R. H. Westveld, assistant professor of forestry at Michigan State College, for a critical review of the subject matter contained herein.

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* Editor's Note — The author's present position is that of Associate Professor of Forest Soils, Mississippi State College, State College, Mississippi.

APPENDIX

COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED

(The scientific names of the trees are those of Dr. C. P. Sargent; the names of the other vegetation, those of Dr. Asa Gray.)

Alder, Alnus incana
American beech, Fagus grandifolia
American elm, Ulmus americana
Balsam fir, Abies balsamea
Basswood, Tilia glabra
Black ash, Fraxinus nigra
Black spruce, Picea mariana
Hemlock, Tsuga canadensis
Jack pine, Pinus banksiana
Labrador tea, Ledum groenlandicum
Large-toothed aspen, Populus grandidentata
Leatherleaf, Chamaedaphne calyculata
Norway pine, Pinus resinosa
Norway spruce, Picea abies
Pin cherry, Prunus pennsylvanica
Red maple, Acer rubrum
Red oak, Quercus borealis
Reindeer moss (lichen), Cladonia sp.
Sphagnum moss, Sphagnum sp.
Sugar maple, Acer saccharum
Tamarack, Larix laricina
Trembling aspen, Populus tremuloides
White ash, Fraxinus americana
White birch, Betula papyrifera
White cedar, Thuja occidentalis
White pine, Pinus strobus
White spruce, Picea glauca
Yellow birch, Betula lutea

LITERATURE CITED

1. Gates, Frank C. Plant Successions about Douglas Lake, Cheboygan County, Mich. Bot. Gaz., 82: 170–182. 1926.
2. Langlade County: A Survey of Its Natural Resources and Utilization. Special Circular, Extension Service of the College of Agriculture. The University of Wisconsin, Madison, Wisconsin. Pages 17–28. April, 1934.
3. Robinove, J. J., and Clark, H. W. The Growth of Aspens in the Region about Douglas Lake, Michigan. Am. Journ. Bot., 17: 169–172. 1929.
4. Sampson, Homer C. Advantages and Limitations in the Use of Soil Types as a Basis of Mapping the Distribution of Vegetation Types. Ohio Acad. Sci., 8: 390–391. 1930.
5. Toumey, J. W. Foundations of Silviculture upon an Ecological Basis. Pages 78–79. John Wiley and Sons, Inc., New York, 1928.
6. Veatch, J. O. Reconstruction of Forest Cover Based on Soil Maps. Michigan Quarterly Bulletin, Vol. 10, No. 3. 1928.
7. —— Soil Maps as a Basis for Mapping Original Forest Cover. Pap. Mich. Acad. Sci., Arts and Letters, 15: 267–273. 1931.
8. —— Agricultural Land Classification and Land Types in Michigan. Special Bull. 231. Mich. Agric. Exper. Sta., East Lansing, Michigan, 1933.
9. Westveld, R. H. The Relation of Certain Soil Characteristics to Forest Growth and Composition in the Northern Hardwood Forest of Northern Michigan. Tech. Bull. 135. Mich. Agric. Exper. Sta., East Lansing, Michigan, 1933.
10. Woollett, M. L., and Sigler, D. Revegetation of Beech-Maple Areas in the Douglas Lake Region. Torreya, 28: 21–28. 1928.

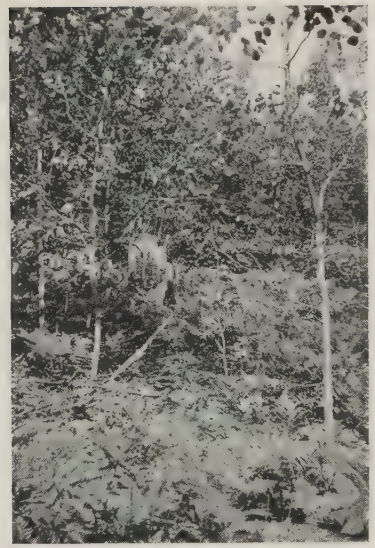

FIG. 1. Present forest cover on pine land which consists of large-toothed aspen, red maple, red oak, and pin cherry. A remnant pine stump is seen in the center background

FIG. 2. A sandy clay lens in the substratum of a loamy pine soil, making for greater fertility

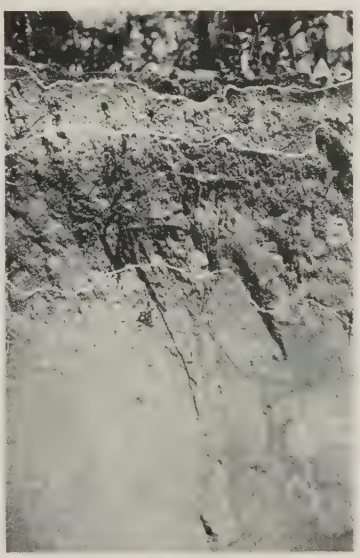

FIG. 3. Profile of a pine soil showing a concentration of roots in the B layer at a depth of 8 to 20 inches below the surface

PLATE XLI

FIG. 1. Present hardwood cover with numerous remnants of the original stand. Sugar maple, American beech, yellow birch, red maple, American elm, and basswood dominate the forest vegetation

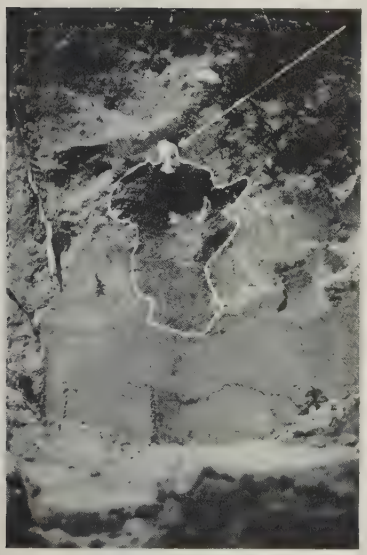

FIG. 2. Yellow substratum of a pine soil showing a darkened area around a limestone fragment. When this dark color exists as a continuous layer, hardwoods are usually associated

FIG. 3. Profile of a sandy loam hardwood soil with the natural soil horizons existing at variable depths. Note the dark B layer in which roots are concentrated

FIG. 1. Typical present cover on conifer-hardwood land consisting of trembling aspen, balsam fir, white birch, hemlock, and red maple

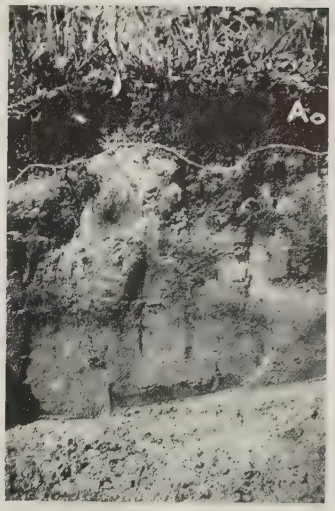

FIG. 2. Soil profile of conifer-hardwood land in which no distinct brown cemented layer is present. Note the 6–12-inch accumulation of organic matter

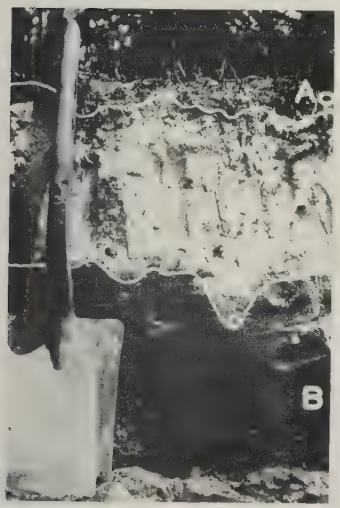

FIG. 3. A conifer-hardwood soil profile characterizing that group of soils having a brown cemented hardpan. Note the thick white A_2 layer

FIG. 4. A dense stand of white cedar, black spruce, balsam fir, and tamarack as the dominant forest cover on swamp land

DISPERSAL OF JACK-PINE SEED FROM SEED TREES AND SLASH

FRANCIS H. EYRE

IN THE earlier days of forestry in the Lake States jack pine was looked upon with scorn. True, it did tend to cover the land after clear-cutting and fire, but as for its value as wood, few dared to predict much of a future. Times have changed. The jack pine, which clothed the landscape after the period of destructive logging, did not stand still but grew into fairly sizable trees, suitable for the production of cordwood material. Pulpwood plants discovered that there were considerable areas from which a supply of this wood could be obtained, and the wood proved to be excellent for the making of certain grades of pulp.

The cutting of this second-growth crop has progressed fairly rapidly without causing foresters very much concern. In portions of the Lower Peninsula of Michigan and in Wisconsin accessible supplies have been greatly depleted, and jack-pine pulpwood is now shipped for rather long distances.

Reproduction, which came in abundantly after logging and fire in the early days, seemed to be a simple matter to obtain, and the literature is full of recommendations on how to manage jack pine. A few of the more important references may be mentioned.

Sterrett (2) indicated that jack pine could be readily reproduced either by clear-cutting in strips or by a general clean-cutting, and leaving five to ten seed trees per acre. In commenting on National Forest practices he said that in Minnesota it was sometimes considered necessary to scatter the slash and burn it in order to open up the cones and let out the seed. In Michigan, however, burning was thought to be unnecessary, and regeneration could be obtained from seed on the ground or from seed trees left after cutting.

Ellis (1) was not quite so positive that jack pine could be easily reproduced. In his opinion fire is usually required to open the cones,

but during dry summers many cones open on the trees, whereas in wet seasons they remain closed.

Zon (3) believed that to obtain reproduction clear-cutting was all that was necessary if the cuttings did not cover too large an area. He expressed the opinion, however, that, where the slash is light and the danger from fires slight, it may with benefit be left scattered and unburned. The sun's heat near the ground would open up enough cones to provide abundant restocking.

The reading of these recommendations would lead to the belief that there is little or no difficulty in obtaining jack-pine reproduction and that the management of this species is indeed simple. There are, however, some differences of opinion among these authors and an almost total absence of concrete evidence and examples of how this or that method worked out in practice. In other words, many of the statements made lack proof, even though they may be substantially correct. More critical observers who have recently taken the trouble to inspect cutover areas and timber sales to see if reproduction really did follow cutting, are becoming frankly skeptical whether we foresters know anything at all about the management of jack pine.

Accordingly, it may be worth while to present some of the preliminary results of cutting experiments and related studies of the Lake States Forest Experiment Station. We have under observation in Minnesota and Michigan some twenty plots devoted chiefly to the study of cutting methods and natural reproduction of jack pine. The records for one of them dates back fourteen years.

A single half-acre plot in a dense 55-year-old stand of jack pine on the Superior National Forest was clear-cut in 1921. The slash was allowed to remain on the ground until 1925, when it was piled and burned. An examination by the stocked-quadrat method made in 1932 indicated that 82 per cent of the area was stocked with aspen or paper birch and 55 per cent with conifers, chiefly balsam fir and spruce, a large part of which was present as advance growth when the cutting took place. Jack pine, however, comprised less than 10 per cent of the coniferous reproduction at the end of eleven years. Even though this small plot was surrounded by a heavy stand of pure jack pine, for some reason it did not reproduce to this species.

A strip cutting made in 1930 in a somewhat similar stand in the same general locality, but containing a 10 per cent mixture of aspen and birch, showed even less satisfactory results. At the end of the

first year after cutting there were no jack-pine seedlings, whereas there was a stocking of 50 per cent of aspen and birch in the clear-cut strips. Many of the aspen suckers were 10 feet high the second year after cutting. Subsequent observations indicate that aspen and brush have completely taken over the area.

There may be places where clear-cutting in either strips or patches has merit, but we have not been able to make the method work in northern Minnesota.

At the Forest Fire Experiment Station at Roscommon, Michigan, we have six slash-disposal plots which throw some additional light on the problem. The timber, a scrubby open stand, was cut clean in 1930, and all the common methods of slash disposal, including broadcast burning, were tried out. The reproduction which came in after cutting was unsatisfactory on all plots. The striking point, however, was the fact that, where the slash was lopped and left, the results were much the best, with no disposal ranking second.

Partial cutting of jack pine in 1926 on the Chippewa National Forest in a 55-year-old understocked stand of jack pine also gave poor results. These plots had an advance crop of seedlings ranging in number from 664 to 1,444 per acre on the ground at the time of cutting. There was some decrease in numbers at the time of logging, due probably to sudden exposure and logging damage, and then a very gradual increase up to 1930 (a very dry year), when the stand of seedlings was from 812 to 1,434 per acre. After this the numbers dropped off to less than those at the time of cutting four years before.

The reaction to cutting in a 60-year-old overstocked stand cut in 1926 on the Superior National Forest was entirely different and much more satisfactory. In this stand there was no advance reproduction of jack pine at the time of logging, although there were some balsam and spruce. The year after cutting a fair stocking of jack-pine seedlings appeared. In 1932, on the plot where 60 per cent of the basal area was removed in cutting, this amounted to 40 per cent of complete stocking with jack pine, the best so far obtained in our cutting plots. Considering all coniferous reproduction, the results were reasonably good. The peculiar thing was, however, that no seedlings of jack pine appeared after the first year.

What was the reason? Were the soil and the seed-bed conditions unfavorable for germination after the first year, or, by some chance, were the seed trees "holding out" on their supply of seed? With the

first question in mind experiments have recently been designed to test out the advantages of preparing the seed bed in various ways. Results of these tests will not be available for another year or two.

To answer the second question, 51 seed traps, each 1/4,000 acre in size, were set out in jack-pine stands of varying density in Minnesota and at two locations in Lower Michigan, namely, on the Huron National Forest and at the Forest Fire Experiment Station at Roscommon.

During a twelve-month period (July, 1933, to July, 1934) nine traps located on the cutting area on the Superior National Forest caught exactly two jack-pine seeds, a rate which would give 888 per acre. Eight traps located in a cutover stand of jack pine during 1932 on the Chippewa National Forest gave almost identical results.

During a fourteen-month period (Aug., 1933, to Oct., 1934) fourteen other traps were placed beneath an 80-year-old stand of jack pine on the Superior National Forest, part of which was cutover during 1934. This stand averaged better than 70 feet tall. Three traps were located in a clear-cut area of 1.7 acres, eight in a partial cutting where about three fourths of the stand had been cut and many large seed trees left, and four in an uncut stand. These traps caught altogether 26 jack-pine seeds, or 7,410 per acre, literally a small handful. During this period there was much hot, dry weather, a condition supposedly ideal for the dissemination of jack-pine seeds. In September, 1934, these same traps caught 2,299 paper birch seeds, or over 600,000 per acre, indicating quite conclusively that the traps are able to catch seeds in case any large quantity is falling. Almost the same number of jack-pine seeds was caught under the uncut stand as on the partial cutting. The clear-cut plot yielded fewer. The comparison between plots is probably unreliable owing to the small number of traps, but the total figures should mean something.

The results obtained in Michigan were quite similar. On the Huron National Forest ten seed traps were located under a 55-year-old jack-pine stand containing 262 trees per acre. The average diameter in the stand was ten inches and the average height 53 feet. During the period from August, 1933, to October, 1934, these traps collected the grand total of two good seeds.

At the same time ten traps were placed in a scrubby jack-pine stand at the Michigan Forest Fire Experiment Station at Roscommon. Over a period of fifteen months 60 seeds were caught. From

July, 1933, to July, 1934, exactly 30 seeds were trapped, or 12,000 per acre, less than one tenth of a pound. As a matter of fact, more seeds were caught in the traps at Roscommon than at the other locations. The stand in this case was more open, and the trees were much shorter than those in the other stands.

No claim is made that the number of seeds collected in these traps is an accurate quantitative expression of the total amount of seed that jack-pine trees annually disperse. It would seem to be entirely apparent, however, from the records presented for a variety of conditions, that jack pine without the use of fire cannot be depended upon as a seed tree.

What, then, is the answer? Obviously, an enormous quantity of seed is contained in the cones of the slash, and germination tests made by our station show that seed, even from old, brown-looking cones which have been on the trees for several years, is of good quality. In our slash-disposal plots at Roscommon it was noted that cones opened up, and around the edges of piles or windrows of bunched slash some reproduction appeared, but beneath heavy accumulations of slash there was no regeneration.

In order to get some idea of the quantity of seed dispersed by slash when scattered a few branches containing 69 cones were placed over a single trap on the Superior National Forest during the summer of 1934. The cover of the trap and the branches were carefully removed once a month and the seeds counted. An especial effort was made to avoid any undue shaking or disturbance which would tend to cause the seeds to be dispersed. At the end of four and one-half months (May 15 to September 30) 2,195 seeds were collected in this single trap, whereas fourteen other traps on the same area caught only an average of 2 seeds per trap from seed trees during a period three times as long. In other words, a layer of slash of this density would disperse nearly 70 pounds, or 8,780,000 seeds per acre. This, indeed, is an extreme contrast to the meager numbers scattered by the seed trees.

To burn slash progressively by swamper burning or to pile and burn it soon after cutting would destroy the greater part of the seed and reduce the chances of getting natural reproduction. If slash can be permitted to lie on the ground exposed to the sun during all or part of a summer season, it stands to reason that a great deal of valuable seed will be dispersed. Afterward, however, it should be piled and burned entirely or reduced in quantity sufficiently to prevent

mechanical obstruction to young seedlings. This operation should tend to shake additional seeds from the cones. By the use of such methods, and perhaps also with the help of some soil preparation, a way may be found to reproduce jack pine.

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LITERATURE CITED

1. Ellis, L. M. 1911. Some Notes on Jack Pine in Western Ontario. Forestry Quarterly, 9: 1–14.
2. Sterrett, W. D. Jack Pine. 1920. U. S. Dept. Agric., Bull. 820.
3. Zon, Raphael. 1928. Timber Growing and Logging Practice in the Lake States. U. S. Dept. Agric., Bull. 1496.

NOTES ON READING AIR PHOTOGRAPHS

HAROLD P. UNDERHILL

SINCE they were first made available to the public in February, 1931, the Geological Survey Division of the Department of Conservation of Michigan has sold hundreds of reduced copies of its original air photograph mosaics to private users at the cost of reproduction. Many of these purchasers have asked for assistance in the interpretation of copy mosaics. It is hoped that the following notes will be of value to them as well as to others who might be confused at first by the multitude of minute details shown on an air photograph.[1]

The term "air photograph" — "air photo" colloquially — is a convenient way of saying "airplane photograph," and it refers to any photograph of the ground taken from an airplane while in flight. In this paper, however, the use of the term "air photograph" is limited to aërial views photographed from a camera position directly above the center of the picture. The scale of the original photographs from which these copies are taken is such that one inch on the print represents one thousand feet on the ground.

A "mosaic" is an assembly of air photographs, trimmed, fitted, and mounted permanently as a unit. Our standard mosaic covers a township of thirty-six square miles. This master mosaic is photographically copied on a scale of two inches to the mile, in which form it is sold to the public as a copy mosaic.

The airplane camera records every detail of the landscape beneath the airplane at the time of exposure. When we are viewing a photograph it is necessary to remember that we are looking at the roofs of buildings, and the crowns of trees, and that, owing to the scale of the print, these and other details are very small. A road may at first appear very narrow, probably because we are accustomed to seeing roads and similar features exaggerated on ordinary maps.

[1] In a paper entitled "Notes on the Assembly of Airplane Photographic Mosaics," *Pap. Mich. Acad. Sci., Arts and Letters*, 20 (1934): 415–434. 1935, the author gives a technical description of the materials and methods used by the Michigan Department of Conservation in making mosaics.

The camera translates each of the natural colors of the landscape into some shade of gray between the limits of white and black.

Water bodies known to be deep photograph almost black, and others known to be uniformly shallow are a light gray, which indicates that the depth of the water, as well as, perhaps, the underwater vegetation and muds, influences the shading of lakes and streams. Beaver ponds, formed by dams across small streams, are invariably as black as the deepest lakes. This fact points to the muddy-bottom hypothesis as being the correct explanation for the dark shades of these shallow ponds. The muddy nature of the bottoms is vouched for by investigations recently made concerning beaver–trout relationships in Michigan.

The few lakes observed which are not of a dark gray to a black shade are uniformly light gray in appearance. Conway Lake in northern Marquette County is said to be shallow, with much bottom vegetation, and its photograph is a light gray which contrasts strongly with those of adjacent deep lakes. Submerged beaches and bars of sand, marl, or limestone are, of course, much lighter than near-by deep waters. The appearance of water varies from the dark shades of clean deep water to the milk white of grossly polluted waters, of which a few examples have come to our attention. Occasionally a water surface showing near the southern border of a print mirrors the sunlight into the camera lens and so prints dead white, or "light-struck," as this effect is sometimes termed. This same water area when photographed from a different angle has, of course, a normal appearance. "Light-struck" water, although commonly unwelcome, sometimes serves to delineate the exact course of a small stream which otherwise would be entirely hidden by an overgrowth of forest canopy. One marsh with a luxuriant stand of grass appeared on the photograph as water. In this case the camera caught the flooded sod, visible through the grass from above although not apparent to the forest mapper on the ground, who reported the curious fact.

Shadows are fully as black as water, and with water they share the distinction of being the darkest features on an air photograph. Because of their irregularity and small size they should rarely be mistaken for water. The exact time of day when the picture was made is sometimes shown by the clock reproduced in the number panel along one side of the photograph. If the time of exposure is known, the shadows of buildings and trees are useful as indicators of the north

point. Photographs are taken only from midforenoon to midafternoon, during which period shadows will swing from a northwesterly to a northeasterly direction. Shadows always point northward in this latitude, and by a brief study of them a print may be quickly orientated with its north side up, which is the correct way to view it. A good estimate of the height of an isolated tree or building may sometimes be made by the aid of its shadow. In some cases the species of individual trees may be guessed, provided the observer is familiar with the timber in the area. Photographs of the scattered Norway pines near Shingleton, on the fringe of the great sandy lowlands of Schoolcraft County, afford data for such experimental use of shadows.

White to light gray lines appearing on a photograph are probably roads, railroads, or fire lines, depending upon characteristics possessed by and peculiar to each. Roads are laid out with square corners and intersections and with sharp curves. They are generally less uniform in width than railroads. Dirt roads are cheaply built, and for this reason dodge obstacles like hills and swamps, rather than cut through or fill them. Farming-country roads generally follow the checkerboard of land lines, whereas sand-plains trails cut across lots without regard to property lines. Trails are an outgrowth of the necessity for the shortest route between two points where land values are low, so that their direct course is deflected only by local topography. There are few straight stretches in a sand trail. Our field men, while engaged in mapping cover in Schoolcraft County with the aid of air photographs, reported a certain logging road shown on a photograph as apparently clean and usable, but it was impassable and almost unrecognizable in the field because of the thick growth of alder brush covering it. The site of a race track is clearly visible in a field southwest of the village of Wolverine, Cheboygan County. Many local residents are unaware that it once existed, since there is no visible evidence on the ground, owing to repeated cultivation of the field. A white line, which was thought to be a good automobile trail, was revealed by our forest mapper in Cheboygan County to be a single plow furrow used in controlling a grass fire. Roads of black bituminous concrete and other dark-surfaced roads are, of course, not white on the air photograph. They are a medium gray and may be easily identified by the usual light-colored side roads, sharp corners, and turns.

Railroads are identified by perfectly engineered curves, connected

by long, straight tangents. On main lines where the roadbed is well kept and the ballast is gravel or crushed rock railroads appear on the photograph as thin white to light gray lines of uniform width. Branch lines show up in any of the darker shades of gray, depending upon the condition of the roadbed. It is not possible to determine from air photographs whether or not steel rails are in place on a railroad grade, except, of course, where evidenced by occasionally visible trains standing on sidings and in motion on main lines. Old roads cleared for logging operations and old railroad grades built for this industry in the past have often become choked with young timber and brush so that one is unable to drive on them. Former pine-logging railroad grades in the Cusino Game Refuge, Schoolcraft County, are easily traced through the virgin hardwoods on the photographs, but are difficult to find in the forest because of the large size of the secondary hardwoods growing on them.

Fire lines might easily be mistaken for roads and, in fact, are often used for roads. In the Pigeon River and Black Lake State Forests in Presque Isle and Cheboygan counties good examples of fire-stopping lines, which are built upon the section, quarter, and eighth lines, are to be found. They form a checkerboard of white lines through the grays of the forest areas, each square outlining a forty-acre tract. Another type of cultivated fire line may be seen on both sides of certain railroads in the Upper Peninsula of Michigan. These are for the specific purpose of stopping fires which might be accidentally started along the railroads by sparks from locomotives equipped with imperfect spark arrestors. The identity of such a fire line along a railroad northeast of Gwinn, Marquette County, was questioned until it was found to stop at the edge of a small lake and continue from the opposite side. A sand-plains trail, which it might have been, would have dodged this water hole and appeared as an unbroken white line on the print. The random firebreak, usually a single plow furrow made across the path of a grass fire for the purpose of stopping it, is also a white line on the photograph, and is easily mistaken for a trail. To the windward of a successfully used plow furrow the burned-over and blackened country contrasts strongly with the normal gray of the unharmed cover on the opposite side of the firebreak.

In farm areas, regularly shaped fields with uniform light gray to white shades are most probably newly cultivated fields. Parallel markings on these areas show the direction of cultivation. Concen-

tric framing of varying shades of gray around a field probably indicate a progressive stage of soil cultivation or of reaping at harvest time. Other fields of a uniform medium gray may be unused lands, pasture lots, green farm crops, or meadows. Cleared lands which at one time were unprofitably cultivated are often overgrown with brush. If all the conditions are good when such an area is photographed, a minutely mottled appearance, due to the many small shadows cast by the brush, will be observed on the photograph. Under adverse conditions of light and foliage, however, it becomes difficult to determine from the print the amount or the size of the brush which may actually be present upon an area having the uniform shading of an alfalfa field. Leatherleaf bogs have the even medium-gray color of a grass meadow, but are a little darker and are often fringed with spruce, cedar, or other conifers.

Cone-bearing trees photograph dark gray to black. Small conifers, when evenly seeded, do have a texture, although it is fine indeed. Average mature conifers have a coarser texture. As a rule, jack pine, cedar, and balsam are darker than the spruces. Proximity to water or lowland is about the only means of differentiating between lowland conifer and upland jack pine, since they photograph about the same as regards texture and color. In fact, it is dangerous to make guesses about the species of trees, either the lowland or the upland types, unless the observer is familiar with ground conditions represented in the photograph in question. As mentioned in an earlier paragraph, the species of occasional isolated trees may sometimes be determined. However, the principal use of photographs in this respect lies in the fact that by them forest types can be identified and their boundaries delineated. Fine texture and dark shade characterize a coniferous area. Their uniformly close-grained appearance from above is about what the reader would expect when a pure stand of thickly stocked spruce or balsam with sharp tops pointing skyward is brought to mind.

Unlike the conifers, upland hardwoods exhibit individual crowns of various shades, depending upon the species and the season. Their broad leaves of summer green or autumn colors reflect more light than do the needles of the cone-bearing trees. This results in light gray crowns, the mass effect of which is darkened by countless small black shadows. Hardwood areas may be described as having the medium-gray color of a "salt-and-pepper" fabric, which is found, upon close

inspection, to be composed of the small rounded forms of individual trees, each casting its shadow.

Pure sand areas appear white on a photograph. Under sand areas may be listed sand roads and trails, sand beaches, sand bars and spits, and sand dunes. Active sand dunes in the Ludington State Park, a few miles north of Ludington, Mason County, are the best example of this type of scenic playground to be found in our files.

In the vicinity of Brevoort Lake, Mackinac County, and again at Manistique, Schoolcraft County, the abandoned beaches of ancient Lake Michigan are strikingly portrayed by gently curving, narrow, concentric bands of light and dark terrain, which represent alternate sand ridges and wet coniferous swamps.

Light-colored bare spots throughout the exposed rock regions of the Upper Peninsula and on Isle Royale are probably outcrops of rock so barren that no trees or other vegetation can grow upon them. Faults across the strike of the country rock on Isle Royale are made obvious by the darker vegetation growing in these zones of fracture.

Sinkholes in the southwest corner of Presque Isle County are strikingly exhibited on air photographs. These conical dry holes have brim diameters as great as five hundred feet and several have depths well over one hundred feet. An indication of their shape and depth can be gained by the shadows covering their southern slopes. These sinkholes and other features having a vertical dimension equal to or greater than that of a small house are very interesting when viewed through a stereoscope.

The stereoscope is an optical device, through which, by means of two sets of mirrors, each eye of an observer views separately one of a pair of overlapping photographs. When nicely adjusted, the photographic images of topographic features, such as buildings, trees, quarries, sinkholes, mountains, and valleys, assume a realistic third dimension of height or depth. The stereoscope cannot be used with a mosaic or a copy mosaic. It is useful only with pairs of overlapping photographs. When they are available, the exhaustive study or detailed mapping of an area is greatly facilitated by the use of a stereoscope and a set of original, overlapping air photographs. It is possible to make accurate topographic contour maps by employing ground methods for skeleton control only, and by completing the map in the office with the aid of air photographs and a stereoscope.

Because of the completeness of detail shown on an air photograph

all users are assured of finding thereon the particular information in which they are interested. Of course, in some photographs trees may conceal the exact course of small streams, trails, or even roads; an occasional fleecy cloud or its black shadow may blot out a small portion of a print; tree shadows may, in places, obscure the exact shore lines of lakes; and smoke from forest fires or industrial plants may entirely blank out considerable portions of the landscape. Perhaps the most common cause of loss of detail in an air photograph is the presence of static.

The term "static" is applied to the white marks on a print which result when sparks of static electricity are discharged within the camera in the presence of the film. Static takes several general forms: hazy white dots the size of a pea, white lightnings branching out radially from a spark center with an overall diameter up to that of a half dollar, and parallel white lines forming an effective hatching across the length of the photograph, which at times renders the print absolutely worthless. There is danger of mistaking some of these static lines for irregular trails in wild areas, and even though no such mistakes are made, the markings detract from the general appearance of a photograph and obscure much detail.

Although an air photograph mosaic is not a strictly accurate map, owing largely to variations in the scale of the original photographs, its several parts are carefully fitted and bear to one another a photographic relationship that is convincing because features difficult to map, such as irregularly shaped lakes and rivers located in almost inaccessible swamps, are reproduced with the same fidelity as the more easily mapped areas. Confidence in the true proportions and completeness of photographic detail are sure to make this new type of map more popular in the future.

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THE SOMERSET–FERGUSON URBAN AREA IN SOUTHEASTERN KENTUCKY

C. STEWART BOERTMAN AND HENRY MADISON KENDALL

THE urban area of Somerset with its satellite, Ferguson, stands out in sharp contrast to the surrounding agricultural landscape of the Highland Rim Plateau just west of the escarpment of the Cumberland Plateau in Southern Kentucky (Map 5). The uneven surface of the Highland Rim, upon which are scattered remnants of forest interspersed with cultivated fields and pastures and occasional irregularly spaced habitations, is obscured in the urban area. Attention focuses rather upon the buildings and upon the varying aspect of the several functional sections within the agglomeration.

Somerset carries on its original function as a political center and has added to it those of distribution and collection of goods. Its satellite, Ferguson, is a result of the acquisition of a still further function, that of transportation. Growth outward from the original nuclei of settlement has nearly joined the two centers, and for all purposes except political the two settlements are one. Geographically, there is one urban area, though it is interrupted in many places by inclusions of vacant or agricultural land.

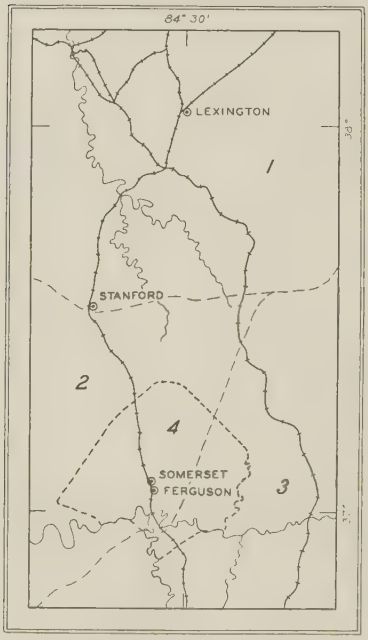
SURFACE CONFIGURATION

The surface of the section of the Highland Rim in which Somerset is located results from both stream and underground erosion. The rocks upon which this surface has developed are limestones of varying resistance. Consequently, in some parts, normal stream erosional forms appear, whereas in other parts characteristic mantled karst forms are the rule. There are considerable unevenness and irregularity in pattern of forms. In general, early mature ridges and valleys, with here and there a sinkhole interrupting the expected level and arrangement, are characteristic.

The probable original nucleus [1] of Somerset occupied the end and

[1] To the present, no map of the original plat of Somerset has been found. Various court records indicate, however, that the section now comprising the

the side slopes of a ridge extending between the valleys of Sinking Creek and one of its tributaries (Map 6). The built-up area has extended from this original site principally northward and eastward onto a less dissected portion of the Highland Rim. The original nucleus of Ferguson lies some two miles to the southeast on a portion of the upland where karst erosion has molded the details of surface. The spread from Ferguson to Somerset has followed along the edge of the valley of Sinking Creek and, in part, occupies the valley slopes and the valley bottom. The valley bottom is very closely followed by the railroad, which forms the physical tie between Somerset and Ferguson, though the narrowness of the valley enforces frequent use of the side slopes. At the present time ridge tops, valley sides, valley bottom, and sinkholes alike are all included in the built-up area of the combined urban unit.



Map 5. Situation of the Somerset–Ferguson urban area. Legend:

1. Blue Grass Basin
2. Highland Rim Plateau
3. Cumberland Plateau
4. Pulaski County

HISTORY OF SETTLEMENT

The populating of the Highland Rim south of Stanford (St. Asaph's) and the establishment of Pulaski County and its county seat, Somerset, occurred soon after the settlement of the Blue Grass. Early in the year 1798 the southeast-central part of the state had a sufficiently large population to demand a county organization and a court nearer than the Lincoln County court at Stanford (Map 5). The state assembly responded by establishing the

commercial core is within the original boundaries. The rectangularity of street pattern in this section, coupled with the orientation of the streets, strengthens this indication.

County of Pulaski, naming the new county after the Polish hero of Revolutionary War fame.[2] Samuel Gilmore, Robert Moderel, John Francis, Nicolas Jasper, and Brazil Meek, being constituted commissioners of peace by Governor Garrard, were to select a permanent site for the county court and to designate the name of the new town. The commissioners met on Tuesday, June 25, 1799, for their first court session at the house of Thomas Hansford.[3]

So heavy was the business before the new county court that it was the end of the year before the court could turn its attention to the purchase of a site for the public buildings. On December 24, 1799, it was ordered that the next session should be held at the home of Nicholas Jasper to view proposals for the location of the county seat.[4] At this and successive sessions the justices listened to the many proposals for the sale of lands to the county but, unfortunately, no record of the number of proposals received or of the debates over the merits and the deficiencies of the various suggested sites is extant. All that is definitely known is contained in the terse entry of the county clerk in the *Court Record Book* regarding the proceedings of February 24, 1801. The court commissioners, after investigating all proposals, finally selected as the best site for the county seat the lands of William Dodson, from whom they proposed to buy a forty-acre tract.[5] On the same day Dodson gave a thousand-pound bond to the court commissioners to transfer the required forty-acre tract in exchange for valuable consideration and two town lots. The tract was to be laid out in a square or a rectangle. Dodson was to have first choice of the town lots, the court was to have second choice, and Dodson was to have third choice.[6] Samuel McKee, James Handgrove, Edward Turner, John Prather, Nicholas Jasper, William Fox, and later Robert Moderel were designated commissioners to let out and superintend the erection of the public buildings — a courthouse, jail, stocks, etc., and a stray pen.[7]

[2] Littell, William, *The Statute Law of Kentucky* (Frankfort, 1810), II : 189. The Act was approved on December 10, 1798, creating Pulaski County from parts of Lincoln and Green counties. The organization of the new county was to be completed so that the county government could begin to function on June 1, 1799.

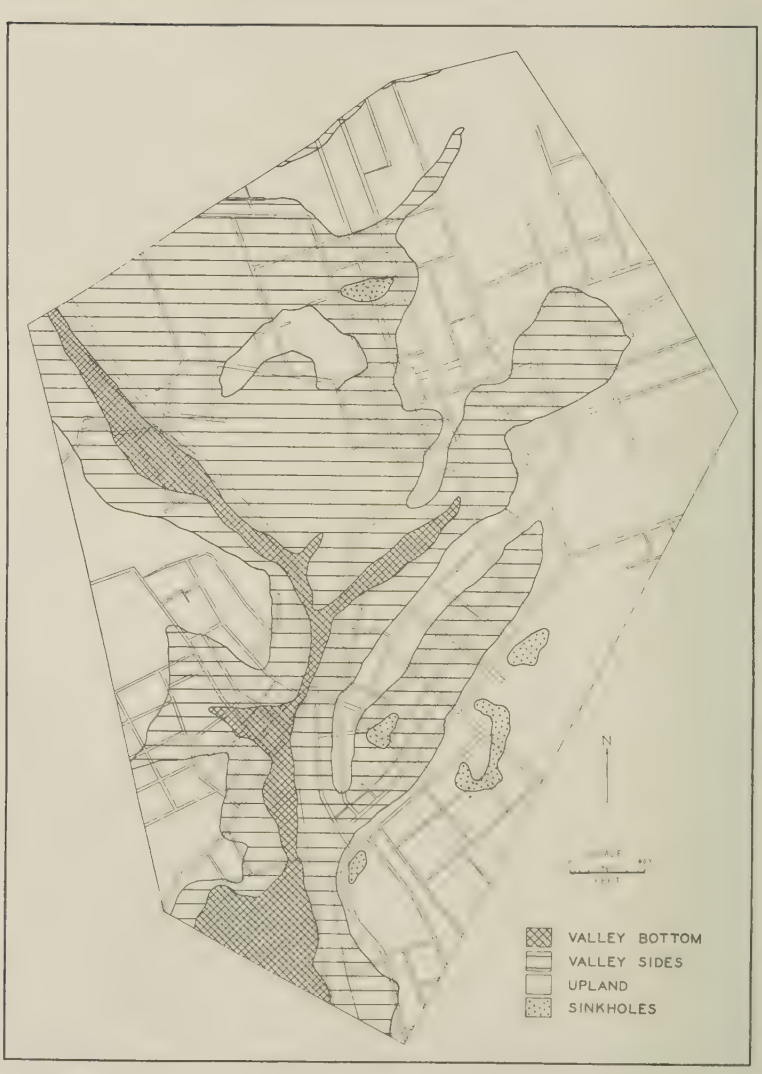
[3] *Court Record Book* (Pulaski County), 1 : 1; Littell, *op. cit.*, II : 190. The enabling act in Littell states the method of naming the commissioners and the time and place for holding the first court session.

[4] *Court Record Book* (Pulaski County), 1 : 29.

[5] *Ibid.*, p. 71.

[6] *Deed Book* (Pulaski County), 1 : 55–56.

[7] *Court Record Book* (Pulaski County), 1 : 72.



Map 6. Site and street pattern of the political city of Somerset

The decision of the court in favor of Dodson's land and Dodson's bond to complete the transaction would seem to settle the question of the permanent site of the new county seat. This was not the case. For some unknown reason the whole matter of the location of the permanent seat of justice of Pulaski County was reopened. Perhaps it was because William Dodson then lived in Tennessee [8] and certain influential citizens felt that the site of the new town should be purchased from a citizen of the Commonwealth of Kentucky. After long, renewed debate the question relating to the site for the public buildings of the county, the court commissioners made their second and final decision on June 24, 1801, again selecting the lands of William Dodson, which were located on Sinking Creek, a branch of Pitman's Creek. The new town was to be called Somerset. Robert Moderel, Nicholas Jasper, Jesse Richardson, John James, Sr., and William Barns were named the first town commissioners.[9] The forty-acre Dodson tract was selected, for it was near the larger agglomerations of population which had been incorporated into the new county.[10] For the forty acres Dodson received $1 and, through the agreement of February 24, 1801, selected town lots 25 and 26 on the public square.[11]

When the choice of the site for the county seat was finally made, a new committee, composed of Jesse Richardson, Nicholas Jasper, James Handgrove, Phillip A. Sublette, John Prather, and Andrew Russell,[12] was appointed to replace the committee of February 24, 1801.[13] Contracts were let for the necessary county structures. John James, Jr., received $38 for the stocks and pillory; William Roberts, $15 for a stray pen; and Francis McGowan, $23 for building a house on lot 40 for the use of the court.[14] This structure was completed by September 22, 1801, for on that date the county clerk noted that the court met at the house built for the court's purpose.[15] Thus two years

[8] *Deed Book* (Pulaski County), 1 : 40–41.

[9] *Court Record Book* (Pulaski County), 1 : 87, 164.

[10] Because of the use of the metes-and-bounds method of survey the location of this tract cannot be given exactly. In the deed of transfer the call is given as follows: "Beginning at a red oak, white oak and a hickory, N 69 degrees E, 80 poles to a stake, N 21 degrees W, 80 poles to a stake, S 69 degrees W, 80 poles to a stake, S 21 degrees E, 80 poles to the beginning."

[11] *Deed Book* (Pulaski County), 1 : 66–69. The deed was recorded on March 15, 1802.

[12] *Court Record Book* (Pulaski County), 1 : 104. This new committee was named on April 28, 1801.

[13] *Ibid.*, p. 72. [14] *Ibid.*, pp. 208–209. [15] *Ibid.*, p. 241.

after the establishment of the county, the county court no longer had to depend on the favor of its members for a place to hold its sessions. The contract mentioned in the records does not inform us as to the character of this permanent structure. No doubt it was similar to the building erected at about the same time for the Wayne County court. This later courthouse was of good hewn logs, 30 by 20 feet, 2 stories high, with 2 floors and 2 doors.[16]

THE GROWTH OF SOMERSET AND FERGUSON

Somerset, from its founding to the Civil War, resembled any of the few surrounding county seats. Its population was small and its connections with the outside world were inferior. The main function of the town was that of governing and serving as a minor distributing center. During the Civil War the town rose in prominence. It served as division headquarters for part of the Union Army of the Ohio which, in the early years of the War, was endeavoring to break the Confederate defense lines which lay along the Cumberland River. It was also the supply base for operations in this sector. The necessity of moving supplies to the advance base forced the Army to improve transportation facilities from the north. It was even proposed by General Burnside to build a railroad from Lexington to Somerset to aid in moving supplies southward and so to relieve the heavy burden placed on the Louisville and Nashville Railroad in transporting supplies into southern Kentucky and northern Tennessee. [17]

The first decade after the War brought the construction of the Cincinnati Southern Railroad. This was later leased to the Cincinnati, New Orleans and Texas Pacific, which is, in turn, controlled by the Southern Railway Company. With the advent of the railroad the nucleus of Ferguson was established. Somerset has remained a division point on the Southern which has meant the continuation of the roundhouse and shops first established at what is now Ferguson when the end of the rails was at Somerset.[18] The importance of the railroad to Somerset is reflected in the considerable increase in popula-

[16] *Court Record Book* (Wayne County), A : 7.

[17] Engineer Gunn made his report to General Burnside on September 18, 1863. For this report see *Official Records . . . War of the Rebellion*, Series I, XXX, Part 2, 599 ff. (Washington, 1872–80).

[18] The railroad was completed from Cincinnati to Somerset in 1877, and trains were operated so far south. It was completed to Chattanooga, the southern terminal, and trains were running over the whole line by 1880.

TABLE I

POPULATION

Census year	Pulaski County	Somerset	Ferguson
1790	.....	....	...
1800	3,161	....	..
1810	6,897	....	...
1820	7,597	....	...
1830	9,500	231	...
1840	9,620	238	...
1850	14,195	412	...
1860	17,201	662	...
1870	17,670	587	...
1880	21,318	805	...
1890	25,731	2,625	...
1900	31,923	3,384	...
1910	35,986	4,491	404 *
1920	34,010 †	4,672	529
1930	35,640	5,506	532

* Ferguson incorporated in 1906.

† McCreary County organized in 1912 from parts of Pulaski, Wayne, and Whitley counties.

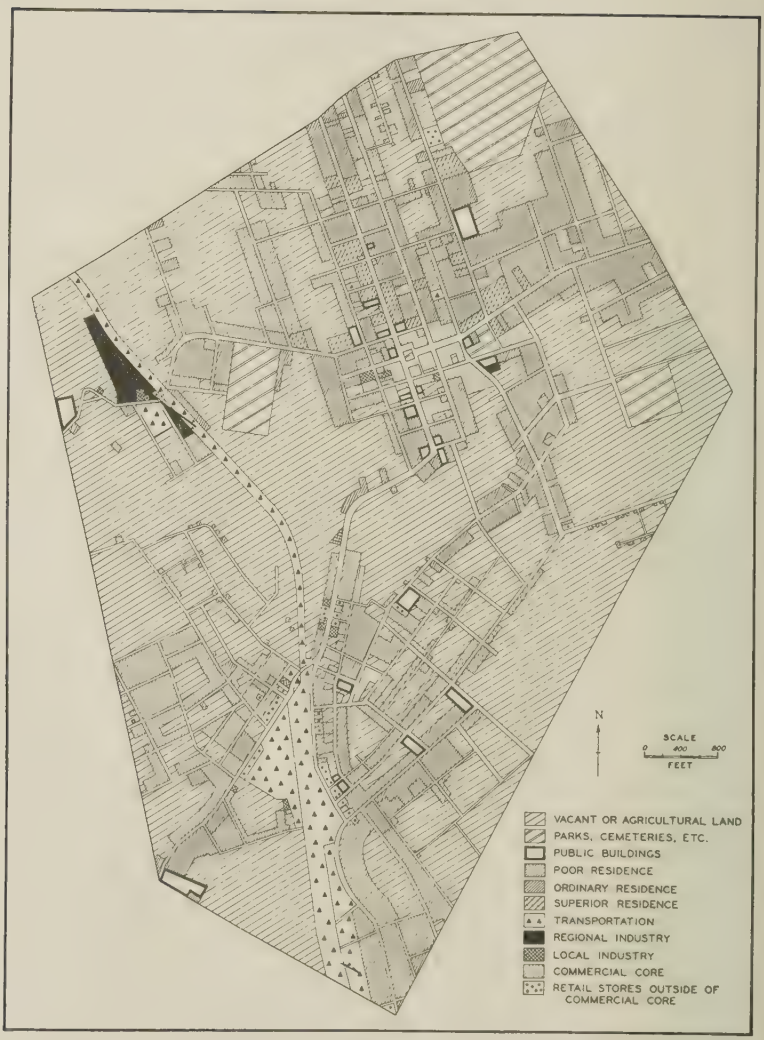
tion during the ensuing decade (Table I). It became a collecting and distributing point of importance for this section of the state. This position it retains today, aided by the improved highways which have been constructed or are planned to radiate from the city.

THE PRESENT-DAY SOMERSET–FERGUSON URBAN AREA

The present main functions of Somerset [19] are those of government and commerce. Transportation is the dominant function of Ferguson. Somerset exists separately as an urban center serving the rural community about it. Ferguson relies to a considerable degree upon Somerset to perform many of the usual urban functions and could not exist in an unaltered form without that center.

Throughout the combined urban area the street pattern is extremely irregular except in the original center of Somerset (Map 7).

[19] The detailed mapping of the functional areas of the political city of Somerset was done by the University of Michigan geography field party under the direction of Professor P. E. James during the summer of 1931, and the mapping of surface configuration was done by P. E. James and H. M. Kendall during the same summer. Only a brief reconnaissance of the political unit of Ferguson was made.



MAP 7. Functional map of the political city of Somerset

There the rectangular pattern of streets gives evidence of a planned arrangement. The orientation of the pattern results from the layout of the original plot of land purchased as a town site. The main street extends from this original unit to form one of the branches to which the rest of the pattern is tied. This street follows southward down the easiest slope of Sinking Creek Valley, crossing the valley bottom where it is relatively narrow and ascending rather more abruptly to the upland on the southwest. Northward from the center the main street continues in its original direction until it is beyond the urban limits. Eastward and westward from the original center prolongations of two of the streets depart from their original direction to conform to easier slopes. All the other streets are tied to this framework. In some parts, as in the southeastern portion of the political city, there is an attempted conformance to surface configuration; in others, as in the western portion of the political city, arbitrary patterns are established.

The courthouse square is the focus of the urban area of Somerset. On the streets leading away from it, particularly toward the east, are the stores which make up the commercial core. The residence districts are principally north and east of this core. There appears to be no regularity in the arrangement of residences of the different classes. Superior residence is just as often backed by poor residence as it is by ordinary residence; nor is there any relationship between the type of land and the type of residence; poor residence is just as frequently found on good sites as on poor ones.

A definite break between the built-up sections of the political city is apparent along an east-west line where the main street begins to descend the east slope of Sinking Creek Valley. South of this line are the homes of the people who work in the railroad shops, and mixed with these homes are retail stores which serve the neighborhood needs. The residences are mostly of a poorer quality than they are to the north and east of the commercial core. They form the northern extension from the political unit of Ferguson. The railroad shops are the nucleus in that instance, and the southern part of the political city of Somerset is more closely connected to them morphologically than to the commercial core of Somerset. There is no regularity of pattern in functional distribution.

The outstanding feature of irregularity is further emphasized by the great amount of vacant and agricultural land which exists in the

urban area and by the complete inadequacy, from a geographical point of view, of the political boundaries.

CONCLUSION

Somerset is an urban nucleus performing the functions of political and commercial center for an agricultural area. Ferguson is an urban area performing primarily the functions associated with transportation. Somerset is a self-contained urban unit; Ferguson is to a considerable degree reliant upon Somerset. There is evidence of a spread toward Somerset on the part of Ferguson. The two centers are not yet well articulated, but they are sufficiently well linked in a rudimentary fashion to be regarded as one urban area. Within this area functional distribution is very irregular, and in only a slight degree is it related to the items of the natural setting.

University of Michigan

THE HIGH PLAINS OF MICHIGAN

CHARLES M. DAVIS

I. INTRODUCTION

THE High Plains of the northern part of the Southern Peninsula of Michigan are formed by a skeleton of moraines filled with sandy outwashes. The moraines not only bound this area but also traverse its surface in a complicated yet quite orderly network of hills. Clay till plains of varying magnitude cling to the bases of these hills and extend out into the seas of sandy outwash which fill the interstices.

The surface features of this upland result from glacial deposition and, as yet, are little altered by erosion. The porous sandy soils absorb the rainfall, so that the few streams have little power. The pattern of the drainage is coarse in texture; streams are far apart and the interfluves are broad and dry. Lakes occupy some of the depressions and swamps border the streams. Over most of the surface the drainage through the soil is excessively rapid, but in some places it is so slow that broad expanses of swamp form the landscape.

Most of this surface is covered by forests of several associations, from the deep shade of beech and maple and the sunny thickets of oak and poplar to the open plains of jack pine and sedge. All these forests bear the scars of cutting and burning.

The present occupance of the area is concentrated on the heavier soils of the more loamy hills and the till plains or around the lakes. Here the houses, fields, and barns of continuous agriculture mark the landscape. Yet even here the land retains the aspect of a frontier; houses and barns made of logs, pastures and fields uncleared of stumps, and the forest sharply bordering on the cultivated land — these things and many others indicate that the occupance is not complete.

The landscapes which make up the High Plains are not static. Twenty thousand years ago, perhaps, they lay beneath the ice of

the continental glacier. As the postglacial climates changed over the area the landscapes were altered accordingly. Then came man with the tools of his culture, which radically altered the aspect of the area. Everywhere in the High Plains one can see the marks of relict landscapes; forests of poplar and oak are thickset with stumps of pines, fields once cleared are now abandoned, mills have saws which are no longer turning, towns decay, and villages have disappeared. A new order has superseded the old; the rotting stumps are hidden by new forests, the cottage has replaced the lumber camp, the fisherman wades the streams where once the lumberjack drove his logs, and the motorcar crosses the sandy plains in the tracks made by the high-wheeled logging carts.

What we see in the High Plains today is but a phase in a process which changes visibly from decade to decade. In three quarters of a century, within the memory of men still alive, or the time in which a pine might have grown from a seedling to a tree, the hills and plains have endured many changes. They have been stripped of their timber, have been burned and reburned, have been settled, cultivated, and abandoned. Nature in her patient way has covered up the wreckage of each change and continues building the forests upon the pattern of the soil.

The position of the High Plains area on the patterns of the world distribution of geographic facts undoubtedly underlies the nature of its geography, but these larger patterns do not orient its internal differentiation.

On a world scale the High Plains lie close to the equatorward margin of the well-watered lands of severe winters. This equatorward position somewhat modifies the long cold winters and the short cool summers and permits the area to be reached at intervals in the winter by warm air masses of tropical origin which break up the unrelenting coldness of the lands farther north. The variations of temperature and rainfall within the area form a regional climatic pattern which apparently has little correlation in the landscape pattern; either the climatic differences are not critical or they are overshadowed by edaphic variations which are not climatically induced.

Although the area lies entirely within the climatic limits of the deciduous forests, the edaphic conditions do not everywhere permit the growth of this kind of forest. The differentiation between deciduous and coniferous forests seems to be a function of varying tex-

ture and moisture content of the soils, which, themselves, in spite of their great diversity, are as a group transitional between the brown-forested soils of the central eastern United States and the podsols of the north.

The relation of the High Plains area to the world distribution of cultural forms is that of a rather sparsely populated region on the poleward margin of one of the central areas of Occidental culture. Its present occupance is the relict of a general withdrawal of population following the collapse of a settlement induced by exploitive lumbering. The agriculture by which this population survives is, in general, an unprosperous and declining portion of the Hay and Forage Region of northeastern United States and southeastern Canada.

These facts of distribution on a geographic scale [1] set broad limits to the nature of things in the High Plains. Within these limits, however, the internal differentiation of the area is oriented by the lineaments of a subordinate or a chorographic pattern the details of which obscure any effects of the larger or geographic pattern.

The principal natural landscape-forming elements, surface, drainage, and soil, and the resultant landscapes within the High Plains are arranged upon the lines of this chorographic pattern, the lineaments of which form the master lines of landscape distribution within the area. The form of this pattern is the shape taken by the glacial front at various stages in its melting and is preserved by the surface features and soil materials laid down by the ice in its retreat. Upon this pattern are oriented the landscapes which collectively express the geographic aspect of the area. Where these are characterized by forests the lines of the fundamental pattern are clear, but where cultural forms are dominant the pattern is vague and obscured by an early stage of occupance not yet adjusted to its differences.

II. THE BASES OF THE LANDSCAPES

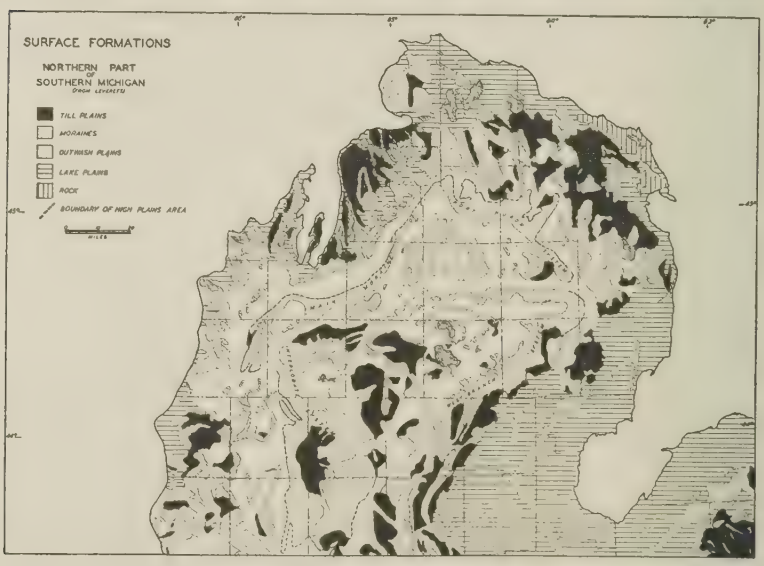
THE SURFACE PATTERN

The surface quality of the High Plains results from the interspersion of moraines, till plains, and outwashes in a pattern left by

[1] "Geographic scale" in the sense of world distribution as contrasted with "chorographic" and "topographic" scales denoting increasing degrees of detail, as advanced by P. E. James in "The Terminology of Regional Description," *Ann. Assn. Am. Geog.*, 24 (2) : 85. 1934.

the retreating ice of the Wisconsin glaciation deeply underlain by previous sandy drift (Map 8). The depth of this underlying drift has been attributed to the interlobate accumulations of previous glaciations,[2] which the Wisconsin glaciation added to and reworked.

The present distribution of surface forms may be explained by the way in which the lobes of the glacier moved across this upland of earlier deposition. From the ice basins, which are the present beds of the Great Lakes, the lobes moved inland, overrode the older drift

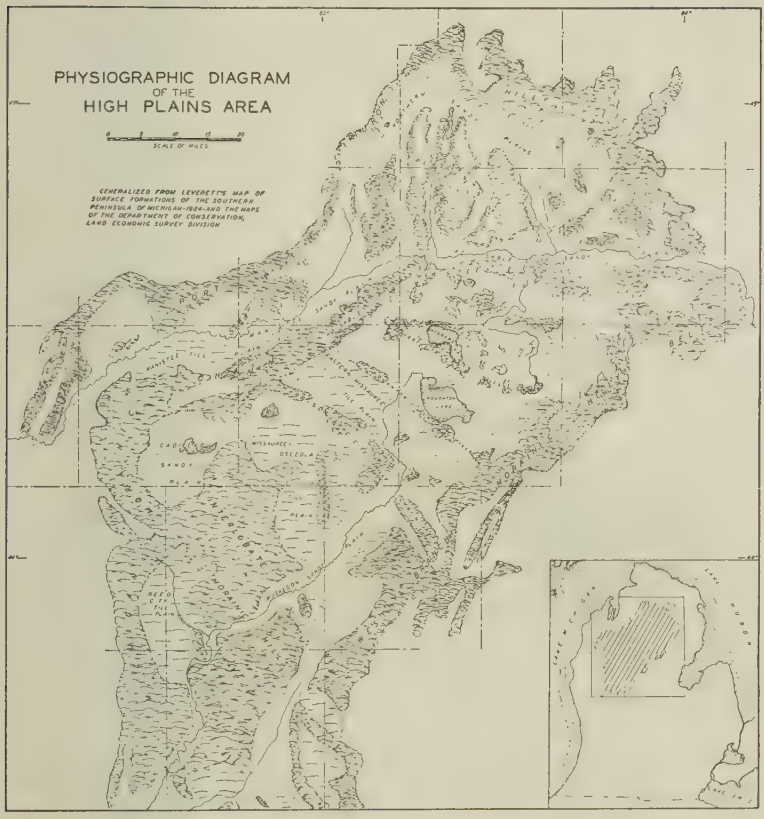


Map 8

and converged; the western ice, or the Michigan lobe, meeting the eastern ice, or the Saginaw lobe, and then moving on southward. At the time of the glacial melting these lobes separated over the High Plains area, forming first the rugged knob-and-basin stretch of the Interlobate moraine (Map 9) and then at the edges of the area the bordering moraines, the Michigan moraine [3] on the west, and the West Branch system on the east.

[2] Leverett, Frank, *Surface Geology and Agricultural Conditions of Michigan, Mich. Geol. and Biol. Surv.*, Publ. 25, Geol. Series 21, p. 114. Lansing, 1917.

[3] For lack of a name in existing literature, this first moraine of the Michigan lobe in the High Plains area is called "the Michigan moraine" in this paper.


PHYSIOGRAPHIC DIAGRAM
OF THE
HIGH PLAINS AREA
SCALE OF MILES
GENERALIZED FROM LEVERETT'S MAP OF SURFACE FORMATIONS OF THE SOUTHERN PENINSULA OF MICHIGAN-1924-AND THE MAPS OF THE DEPARTMENT OF CONSERVATION, LAND ECONOMIC SURVEY DIVISION

Map 9

The gap between the Michigan and the Saginaw lobes was spanned by thinner ice, which melted rapidly, forming a recess toward the northeast. The progress of this retreat is marked by four chains of moraines which connect the Michigan with the West Branch system; between some of them lie broad till plains. The northeastern extent of this melting recess is marked by four large plateau-like morainic masses close to the northern corner of the High Plains area.

Continued melting removed the ice from the High Plains, but it made one more readvance, which carried the lobes as far as, but

not into, the area. For a long time the melting edge of the glacier lay upon the sides of the upland and built up the Port Huron moraine, which forms the northwestern and northeastern boundary of the High Plains area from the Manistee River to the Au Sable.

Within this skeleton of moraines lie four principal and several smaller till plains, but most of the area is covered with sandy outwash laid down by the waters of the glacial melting. In some places these outwashes are wet and waterlogged, but ordinarily they are deep and dry. The depth and the porosity of the underlying material are strong factors in accounting for the aridity of most of the soils upon the plains.

The pattern made by the moraines, till plains, and outwashes in the High Plains area (Map 8) is the skeleton of the master lines upon which both the past and present landscapes have been distributed.

THE DRAINAGE PATTERN

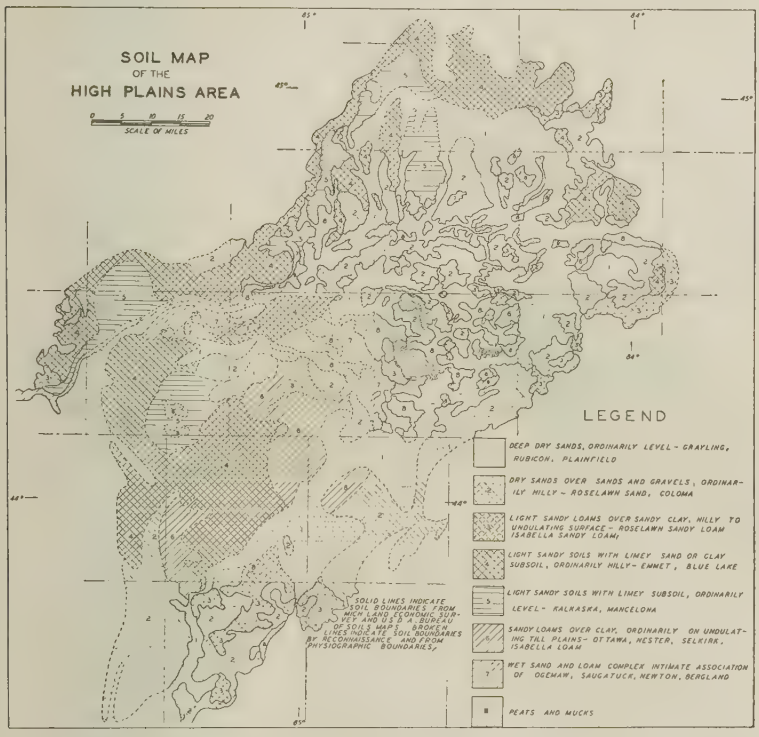
The water from the glacial melting was carried away from the upland and to the lakes at the time of the glacial retreat. The courses of the glacial rivers were determined by the ice lobes, which were at the same time laying down the surface features. The present rivers flow in the old glacial channels as distinctly underfit streams, and the pattern which they make is one inherited from the glacial front. They appear to bend their courses around moraines (Map 9), but the cause-and-effect relationship cannot be inferred, since both are the simultaneous product of the same agent. They should not, therefore, be classed as simple consequent streams, but as consequences of ice forms which no longer exist.

The knob-and-basin surface of the moraines, particularly on the western side of the High Plains, is dotted with numerous small lakes in all stages of the process of being filled in by vegetation (Pl. XLV, Fig. 4). The outwash areas are similarly pitted, but most of these pits are dry. In a few places large lakes, such as Higgins, Houghton, and Missaukee, have resulted from depressions on till plains or pits formed by large ice blocks left buried by the glacial retreat.

The patterns made by the lakes and streams are oriented upon the master lines traced by the surface. The streams and landforms are simultaneous phenomena of the same agent, and the lakes are subsequent features on the same pattern. The association of the

poorly drained areas, of which swamps are the characteristic landscape expression, with the lines of the master pattern, is equally clear but somewhat more complicated.

The glacial ice in its retreat built the moraines and till plains, but the waters from its melting laid down the outwash. Conse-


SOIL MAP
OF THE
HIGH PLAINS AREA
SCALE OF MILES
LEGEND
DEEP DRY SANDS, ORDINARILY LEVEL - GRAYLING, RUBICON, PLAINFIELD
DRY SANDS OVER SANDS AND GRAVELS, ORDINARILY HILLY - ROSELAWN SAND, COLOMA
LIGHT SANDY LOAMS OVER SANDY CLAY, HILLY TO UNDULATING SURFACE - ROSELAWN SANDY LOAM ISABELLA SANDY LOAM
LIGHT SANDY SOILS WITH LIMEY SAND OR CLAY SUBSOIL, ORDINARILY HILLY - EMMET, BLUE LAKE
LIGHT SANDY SOILS WITH LIMEY SUBSOIL, ORDINARILY LEVEL - KALKASKA, MANCELONA
SANDY LOAMS OVER CLAY, ORDINARILY ON UNDULATING TILL PLAINS - OTTAWA, HESTER, SELKIRK, ISABELLA LOAM
WET SAND AND LOAM COMPLEX INTIMATE ASSOCIATION OF OGEMAW, SAUGATUCK, NEWTON, BERGLAND
PEATS AND MUCKS
SOLID LINES INDICATE SOIL BOUNDARIES FROM MSC "LAND ECONOMIC SURVEY" AND U.S.D.A. BUREAU OF SOILS MAP. BROKEN LINES SOIL BOUNDARIES BY RECONNAISSANCE AND FROM PHYSIOGRAPHIC BOUNDARIES.

Map 10

quently, the outwash may veneer heavier deposits with a thin mantle of sand, which causes slow drainage and a high water table. In the recess between the Michigan and the Saginaw lobes, the melting ice deposited heavier material in the form of till plains. Close to the high Interlobate moraine these have remained uncovered as the principal till plains in the area, but to the northeast this heavier material has been covered with a thin layer of outwashed

sand, forming the great swampy district around Houghton and Higgins lakes.

THE SOIL PATTERN

The texture of the material which was deposited as a moraine, a till plain, or an outwash is generally characteristic of the particular landform. For this reason the pattern of the soils which result from the weathering of this material shows a general correspondence with the pattern of the surface (Map 10). Where this weathering took place under conditions of normal drainage, it has resulted in sandy soils of podsolic nature.[4] Where the drainage is slow the soil development proceeds in a manner different from that upon the well-drained material; vegetation is the chief instrument in building and the resultant soils are the organic group, peats and mucks (Map 10, No. 8). Intermediate between these two groups is another, which is formed by an intimate association of wet sands and loams found on somewhat poorly drained till plains and along streams (Map 10, No. 7).

The material deposited in the various classes of glacial landforms had characteristic texture. The heavier clayey and somewhat stony material of the till plains weathered into heavy sandy loams (Map 10, No. 6); the heterogeneous material of the moraines into light sandy loams and loamy sands (Map 10, Nos. 2–4); and the outwashes into light loamy sands and sands (Map 10, Nos. 1, 5). In addition to the texture differences, there seem to have been considerable differences in the composition of the material deposited in the western part of the area by the Michigan lobe and that deposited in the eastern part of the area by the Saginaw lobe. The former contained more limestone [5] and clay, which produced in weathering a cementation which has given these soils a somewhat higher moisture content than the similar soils from the material deposited by the Saginaw lobe. This difference in acidity and moisture content between the morainic soils of the western moraines (Map 10, No. 4) and the eastern morainic soils (Map 10, Nos. 2–3), and corresponding

[4] Veatch, J. O., Schoenmann, Lee Roy A., and others, *Soil Survey of Kalkaska County, Michigan*, U. S. Dept. Agric., Bur. Chem. and Soils, Series 1927, No. 28, p. 32. 1931.

[5] Leverett, Frank, and Taylor, Frank B., *The Pleistocene of Indiana and Michigan and the History of the Great Lakes*, *U. S. Geol. Surv., Mon. 53*, p. 224. Washington, 1915.

differences between the western and the eastern outwash soils (Map 10, Nos. 5 and 1, respectively) is not great, but apparently is ecologically critical, for the western soils bore broadleaf or mixed forests, while the eastern bore coniferous forests. In the present landscape quality of the High Plains area this difference is even more striking, for the western soils have been taken up as the agricultural districts, while the eastern soils have fallen into wild land and public ownership.

On the geographic scale [6] climatic forces are the primary agents in soil formation, but the diversity and the intimate association of the soils of the High Plains must be attributed to their recent origin from different kinds of glacial deposits. Although the soils of the western and the eastern parts of the area are different because of the lithologic differences of the materials brought in by the two lobes of the glacier, still the pattern of distribution of the soils in all parts of the High Plains area correlates strongly with the pattern of the surface features. Thus upon the chorographic mould is drawn the third of the master lines of the landscape-forming elements.

THE DEVELOPMENT OF THE ORIGINAL FOREST COVER

The history of the cover in the High Plains has been one of constant change. From the sterile sand laid down by the glacier ten or twenty thousand years ago there developed a succession of forests ending in that which the lumbermen cut away, and since then the hills and the plains have been more or less mantled with trees.

Vegetation is seldom in a static condition. Even without the interference of man a forest passes through a series of stages, each of which prepares the way for its successor, until the progression reaches the type most favorably suited to the climate. If the nature of the soil is such that the climatic climax cannot be supported, the succession cannot go on to its ultimate. Thus, in an area of diverse soils, several individual associations might be found, each of which represents an arrested step toward the climatic climax.

Upon the master lines of the surface, drainage, and soil the development of the forest cover proceeded, conditioned by three factors: normal forest succession, climatic change, and soil differences. Whitford, [7] without recognizing climatic change, traces the

[6] See note 1.

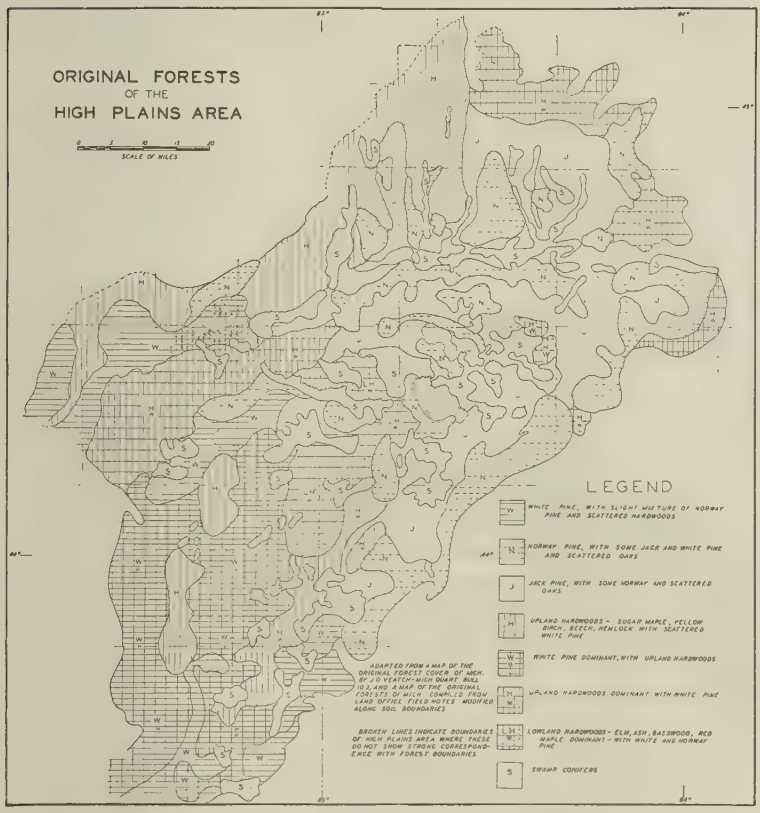
[7] "Genetic Development of Forests," *Bot. Gaz.*, 31: 289–325. 1901.

history of the forests of northern Michigan from the heath stage following glaciation through the spruce and the pine, and eventually to the broadleaf climax. Each association was succeeded by another after it had added humus and thus changed the condition of the soil. The study of fossil pollen in peat bogs has produced convincing evidence of postglacial climatic change. Sears,[8] in summarizing the results of American and European investigators, has postulated a series of five definite postglacial climates. The period immediately preceding the present is postulated as a warmer drier stage, which gave way to the cooler and more moist conditions of the present.

Whatever may have been the nature of the previous cover, the warm dry period, postulated above, must have induced a vegetation radically different from that which has existed in recent times. Most of the soils of the High Plains are droughty, and the small amount of moisture available to plants is one of the chief factors in limiting forest growth. Any considerable decrease in moisture from that which exists at present might prevent forest growth over much of the area and limit the heavier soils to the production of the more xeric trees. With the advent of cooler and more moist conditions, accompanied by increase in soil moisture, the forest succession toward the climatic climax began, from jack pine, through Norway pine and white pine, to the climax of the broadleaf associations. At the time of lumbering the forests of the High Plains represented all stages and mixtures of stages of such a progression which had been stopped or slowed down by the varying aridity of the soils (Map 11). The pattern of this original forest is oriented along the master lines of surface, drainage, and soil.

The drier eastern parts of the High Plains area were originally covered with pines. On the deep, dry sands of the outwash plains the forest succession had not progressed beyond the stage of an open stand of jack pines with a lighter or a heavier admixture of Norway pines and a few white pines indicating the direction of change. On the somewhat heavier soils of the morainic hills the forest succession had gone one step farther. Here the Norway pine was the dominant species, accompanied by a heavy mixture of white pines and a scattering of oaks. On a few of the more moist outwashes,

[8] "Climatic Change as a Factor in Forest Succession," *Journ. For.*, 31 : 934–942. 1933.


ORIGINAL FORESTS
OF THE
HIGH PLAINS AREA
SCALE OF MILES
LEGEND
WHITE PINE, WITH SLIGHT MIXTURE OF NORWAY PINE AND SCATTERED HARDWOODS
NORWAY PINE, WITH SOME JACK AND WHITE PINE AND SCATTERED OAKS
JACK PINE, WITH SOME NORWAY AND SCATTERED OAKS
UPLAND HARDWOODS - SUGAR MAPLE, YELLOW BIRCH, BEECH, HEMLOCK WITH SCATTERED WHITE PINE
WHITE PINE DOMINANT, WITH UPLAND HARDWOODS
UPLAND HARDWOODS DOMINANT WITH WHITE PINE
LOWLAND HARDWOODS - ELM, ASH, BASSWOOD, RED MAPLE DOMINANT - WITH WHITE AND NORWAY PINE
SWAMP CONIFERS
ADAPTED FROM A MAP OF THE ORIGINAL FOREST COVER OF MICH. BY J.O VEATCH-MICH QUART. BULL. 10 A, AND A MAP OF THE ORIGINAL FORESTS OF MICH. COMPILED FROM LAND OFFICE FIELD NOTES MODIFIED ALONG SOIL BOUNDARIES
BROKEN LINES INDICATE BOUNDARIES OF HIGH PLAINS AREA WHERE THESE DO NOT SHOW STRONG CORRESPONDENCE WITH FOREST BOUNDARIES

Map 11

particularly in plains along the Manistee and the Muskegon rivers, the white pines occurred as an almost pure stand.

In the western parts of the area the succession had gone forward to the stage of dominance of, or a heavy mixture of, the broadleaf trees. The genetic differences between the eastern and the western soils (see p. 310) were critical between the pines and the broadleaf trees at that stage in the succession. On the Interlobate and the southern part of the Michigan moraines the white pine was still the dominant tree, but the maple, birch, and beech were present as a heavy subdominant association. Here, apparently, the succession was

somewhat slower than in the northwest, and the broadleaf trees had not yet supplanted the pines. Farther north, on the northward extension of the Michigan moraine (Map 11), the broadleaf trees had become the dominant association and the pines the subdominant. Still farther north, on the western limb of the Port Huron moraine and some of its outwashes, the broadleaf climax had been closely approached, since only relict white pines indicated the course of succession.

On the heavier soils of the till plains the succession had gone on to the broadleaf stage in all parts of the area, but in these situations there was a differentiation between the well-drained and the poorly drained till plains. Where the sag-and-swell surface was well developed and the drainage rapid, the forest cover was dominantly maple, birch, and beech, with a greater or a lesser admixture of white pine. In areas of flatter surface and heavier soils and slower drainage the broadleaf trees were represented by the lowland association, elm, ash, basswood, and red maple, mixed in varying degrees with white pine and Norway pine.

The succession of forest associations on the upland soils had apparently not been matched by a similar succession on the peats and mucks. The most common association on the organic soils is the cedar spruce-tamarack forest, with the general association of the balsam (Pl. XLV, Fig. 4). It would appear that this is the most persistent of all the types in the High Plains through the vicissitudes of time and climatic change. Forest differentiation in the High Plains area, both areally and through time, is closely related to available moisture in the soils, and in this factor the waterlogged areas seem to have been fairly constant.

The distribution of the original forest cover of the High Plains area in such detail as it can now be reproduced oriented itself upon the pattern of the master lines drawn by the surface, drainage, and soils. In the eastern part the more porous soils formed from the material deposited by the Saginaw lobe were almost entirely covered with pine forests; the dry outwash sands, with jack pine; the more moist outwashes, with white pine; the sandy moraines, with Norway pine; and the till plains, with a mixed forest dominated by the broadleaf trees. In the western part the more retentive soils resulting from the deposition of the Michigan lobe were almost everywhere covered with broadleaf trees or mixtures in which the broadleafs

were dominant or becoming dominant. The swamp association was found everywhere throughout the area on the poorly drained soils.

SEQUENT OCCUPANCE

Into this slowly changing fundament of the High Plains came man; at first, primitive man, whose culture included only few and simple techniques for utilizing the resources of the land; and later, men of more advanced culture, with tools which changed the superficial aspect of the forest cover, but not the master lines upon which the distributions of phenomena are oriented.

It is not known with any degree of certainty at which point in its development this area came to be inhabited by the Indians. Except along a few of the larger lakes and rivers the Indians did not live in the pine woods of the eastern part of the High Plains.[9] The broadleaf forests of the western part of the area were more attractive, but even here the population was scanty in comparison with that along the shore of Lake Michigan and in the Saginaw Valley. For some thousand years or more the Indian lived in the forests of Michigan, but he made no significant changes in the fundamental landscapes and left no traces of his occupance in the present landscapes. His canoe routes, perhaps, marked the way for the communications of the fur traders, but, in the High Plains at least, there are today few landscape features which can be ascribed to the Indians.

In the seventeenth century the French voyageurs and the Jesuits joined the territory which is now Michigan with the great fur-trading empire which focused on Montreal. These first communications which connected northern Michigan with the rest of the world were largely by canoe and did not extend far inland. The French were interested in fur-bearing animals and Indian souls, and since there were few of either in the area of the High Plains, it remained unoccupied. The British had pushed into southern Michigan from New York and were in competition with the French for the fur trade when the territory became theirs as a result of the French and Indian War. The period of the British control was so short (1752–87) that it added little to the French settlements. It was not until the American settlers began to pour into southern Michigan that

[9] Hinsdale, W. B., *Distribution of the Aboriginal Population of Michigan*, Occas. Contrib. from the Mus. of Anthropol., Univ. of Mich., No. 2, p. 7. 1932.

the forests were cleared and agriculture took over the land and permanent settlement approached the southern limits of the High Plains area.

The occupance of the High Plains by the lumbermen began with the advent of the "land-lookers," who, in the 1850's, were prospecting in the area for timberlands. The Land Office had surveyed the country and marked out the township and section lines; the land, including its timber, was on sale at $1.25 per acre.

There were two phases to the lumbering operations in the High Plains. In the first of these, river logging, the timber was floated down the streams to the mills. The area which could be tapped by this type of operations was limited to that within easy reach of the main rivers and their principal tributaries. While river logging made roads and trails along the streams, there were not many permanent settlements in the cutting areas, and the mills were located downstream, usually close to the lakes. In the second, or railroad, phase, which quickly followed river lumbering, the railroads replaced the streams as the main carriers, and, since logging branches could be built almost anywhere, this effectively cleaned up the rest of the timber (Pl. XLIII, Fig. 1). The mills were located along the main railroads close to the cutting areas, thus bringing settlements and, in many circumstances, the beginnings of agriculture into the forest lands.

The distribution of the occupance of the lumbermen was oriented along the three railroad lines which had made their way through the High Plains area in the early 70's. Every few miles as these railroads pushed toward Mackinaw, mills were set up to exploit the timber. Each of these was a nucleus for settlement; around some of them the cutover land was taken up for garden or crop agriculture. Most of these little settlements perished with the passing of the lumbering, but some survived as the foci of the communications of the hopeful settlers who took over the land after lumbering.

It is not practicable here to describe the rapid rise and the equally rapid decline of the lumbering industry in the area of the High Plains. The operators bought the land, constructed their transportation, cut off the timber, and got out. The lumbering was done in the spirit of the expansion of the frontier. Whether or not it might have been done in some other manner to yield greater social and economic benefits is a matter of question. As a fact accomplished,

it was the turning point in the development of the landscapes and the source to which may be traced many of their present characteristics.

THE FACTORS WHICH CONDITIONED THE LANDSCAPES AFTER LUMBERING

The lumbering operations had radically altered the superficial aspect of the original landscapes in the High Plains area. A new cover was to develop upon the master lines of distribution, conditioned not only by the character of the soil and the drainage, but also by new circumstances which remained from the occupance of the lumbermen. These new circumstances are loosely grouped under five heads: fires and their consequences, the development of the present forests, the beginnings of the system of communications, the economic consequences of lumbering, and the origin of the settlement. These, working collectively and often simultaneously on the old fundament, made the modern landscapes.

FIRES AND THEIR CONSEQUENCES

The conditions which were left behind by the lumbermen greatly increased the chances for fire on the land. The slash from the cutting operations was scattered on the ground, and after a year this became dry and made excellent fuel for a ground fire. It was expected that the débris from the lumbering would be burned when the country was taken up for farming; in fact, the trees were often felled so that the slash would make windrows to facilitate burning. The numerous men in the woods, logging railroads, mills, and settlers increased the agencies which might start fires. There was, furthermore, no equipment to combat fires in the woods; indeed, there was no desire to stop a fire which was "burning off the brush" unless it threatened standing timber or camps. The idea that the fires were burning out some of the humus in the soil or ruining the game cover was not yet widely recognized.

After the cessation of the lumbering operations and the collapse of most of the settlements which these had attracted, the pinelands became almost deserted. The fire season began in the middle of the summer and lasted until the fall rains dampened the cover. The pungent odor of burning wood and the sight of reddened sunsets through smoky air were the everyday experiences of those who

traveled through the wild lands. There was no organization to do anything about it. When fires approached settlements they were fought by backfires and plowing, while the clergy assisted with prayers for rain. Away from the towns, where new forests were growing to replace those cut away, the fires burned fiercely year after year, "clearing off the brush" (Pl. XLIII, Fig. 2).

The changes in the character of the cover which developed after lumbering must be attributed more to the fires than to the cutting. The lumbermen nowhere cut the land clear of timber; there were always young and "cripple" trees left, and these might have reproduced the forests except for the fires. Repeated burnings effectively destroyed the seed trees of certain species and introduced a new factor into the forest succession, for some trees survive fire better than others.

THE DEVELOPMENT OF THE PRESENT FORESTS

The first stage of the development of the forests in the High Plains area opened with the retreat of the glacier and had proceeded toward the development and distribution of climax and subclimax types roughly corresponding with the pattern of the soils. The progress of this phase was interrupted and terminated by lumbering and fires, and the stage was set for a new cycle under conditions somewhat different from the first.

On the dry sandy plains, which had formerly been covered with an open forest of jack pines and Norway pines, with a few white pines present, the jack pines alone returned in abundance and formed a heavy clumpy cover (Pl. XLV, Fig. 2). The jack pines are natural "fireweeds." The cones which enclose the seeds are tight resinous jackets, which neither rot nor open easily, but when a fire burns over these buried cones they pop open and the seeds sprout. The dominance of the jack pines on the plains today lies, perhaps, in this ability to withstand burnings and in the reduction of the Norway pines by fire until they were incapable of reseeding the plains in competition.

The dry, gravelly, sandy, morainic hills of the eastern part of the High Plains, which originally bore the forests dominated by Norway pines, are now covered by the oak association. The oaks also owe their prominence to fires. In the original forests of these hills the oaks were present, but were distinctly subdominant trees, which

might be considered the forerunners of the broadleaf association. The fire-resisting qualities of the oaks result from their ability to sprout from undamaged roots after the rest of the tree has been killed by fire. Repeated burnings reduce the oaks to clumpy brush, but serve to kill out other trees and to emphasize the dominance of the oaks (Pl. XLV, Fig. 1).

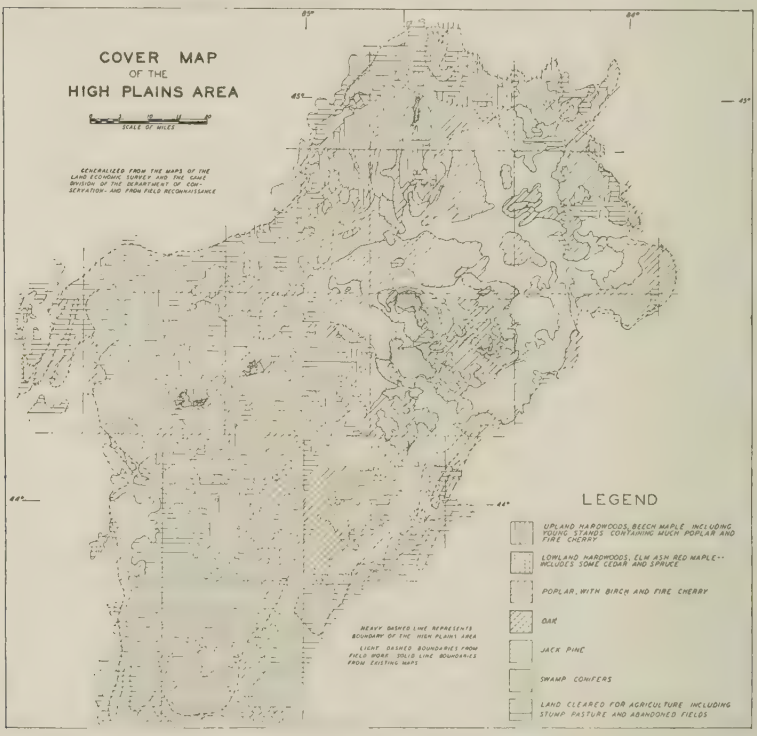
On the soils which were somewhat more moist than those bearing the jack pines and the oaks and where agriculture did not immediately take up the land, the poplar–birch association, which had hitherto existed as a minor type, came swiftly into prominence and covered great areas of land. The widespread distribution of this association may be accounted for by a combination of facts: the ease with which the seeds are spread by the wind, the rapidity of growth, and the wide range of tolerance of soils. The poplar–birch association also includes in some places the subdominant attachment of the fire cherry and the red maple, and the poplars themselves are found in almost all the other associations in the High Plains area. In spite of its wide areal distribution the poplar–birch is an ephemeral type. It rapidly occupies burned areas and develops a heavy forest growth, but, unless repeated fires occur, pines, oaks, or other trees force it out.

In the eastern part of the High Plains, the old pinelands, new cover associations, jack pine, oak, and poplar birch have taken over the land. Although somewhat complicated by the ubiquity of the poplar–birch, the distribution of these new types (Map 12) follows closely the master lines of the surface, drainage, and soils which conditioned the distribution of the original forest types.

The cutting and burning which so radically altered the character of the forests in the eastern part of the High Plains did not so strongly change the western part. There the soils which bore the forests of mixed pines and broadleaf trees were appreciably more fertile, and the agriculture which followed in after the lumbering spread and took over much of the land. Those areas which were not so occupied have been slowly reproducing the original broadleaf cover, but without the relict pines. Where the land has not been heavily burned the seed trees of the maple, birch, and beech on the uplands and the elm, ash, and red maple on the lowlands are struggling to dominance against the quick-growing poplars (Pl. XLV, Fig. 3). On land which has been heavily burned, or where the soil

is so poor as to make the growth of the broadleaf trees slow, the poplar has dominated the forest.

The pattern of the distribution of the new forests in the western part of the area is not nearly so clear as it is in the eastern part. The occupance is of an early stage, and is not yet adjusted to the


COVER MAP
OF THE
HIGH PLAINS AREA
SCALE OF MILES
GENERALIZED FROM THE MAPS OF THE LAND ECONOMIC SURVEY AND THE CLAYE DIVISION OF THE DEPARTMENT OF CONSERVATION AND FROM FIELD RECONNAISSANCE
HEAVY DASHED LINE REPRESENTS BOUNDARY OF THE HIGH PLAINS AREA
LIGHT DASHED BOUNDARIES FROM FIELD WORK SOLID LINE BOUNDARIES FROM EXISTING MAPS
LEGEND
UPLAND HARDWOODS, BEECH MAPLE INCLUDING YOUNG STANDS CONTAINING MUCH POPLAR AND FIRE CHERRY
LOWLAND HARDWOODS, ELM ASH RED MAPLE-- INCLUDES SOME CEDAR AND SPRUCE
POPLAR WITH BIRCH AND FIRE CHERRY
OAK
JACK PINE
SWAMP CONIFERS
LAND CLEARED FOR AGRICULTURE INCLUDING STUMP PASTURE AND ABANDONED FIELDS

Map 12

lines of the soil pattern, and the soil-tolerant poplars further obscure the master lines of distribution.

The swamp forests were less affected than any others by the lumbering operations. The white cedar was the only tree for which there was much commercial demand. Where the swamps were heavily cut over and then burned, the land grew up in places into dense thickets of poplar, alder, and willow. In most of them, how-

ever, the landscape quality of the forest remained the same both before and after the lumbering period.

THE BEGINNINGS OF THE SYSTEM OF COMMUNICATION

Previous to the time of the lumbering the High Plains was an area almost isolated from the rest of the United States. The main lines of the railroads, which were built in part at least to facilitate the lumbering, provided these connections. The railroads and their many logging branches and the fine network of the lumbering roads and trails were primarily constructed for the purpose of getting the logs to the mills and the finished products to the market. The system was not laid out with the idea of its future utility to settlers who might take over the land. In spite of its origin the system of lumbering communications served the needs of the first settlers and still provides the cultural circulation through the unsettled parts of the area.

The lumbering roads enabled the settlers to get into the country and provided communications for a short while, but they were not very well suited to the circulation of an agricultural district. Where settlement endured they were replaced by a right-angled road pattern. Those parts of the original lumbering communications which still persist in the landscapes of the High Plains are relicts of an occupance which has passed. They are preserved because no other features have supplanted them or because they have become functional in the communications of the new occupance. The lumbering roads do not underlie the pattern of the present circulation, but they served the purpose until another way could be set up.

THE ECONOMIC CONSEQUENCES OF LUMBERING

The lumbermen regarded the pinelands as part of their stock in trade. They had purchased the land for a fraction of the stumpage value and, when the timber was gone, the land was a by-product to be disposed of at a profit, if possible, or discarded if necessary. Neither public nor private consciousness believed that the lumber industry owed anything to society for the harvest which it had reaped without sowing. The business of the lumberman was timber, not land, but the land remained. It was supposed, generally, that agriculture would follow after lumbering and that a period of adjustment and tax delinquency in between was inevitable.

In the western parts of the High Plains this anticipation was realized, but in the east the scattered agricultural settlements collapsed with the withdrawal of the lumbering industry. In a few places this was bolstered up by land booms which served only to delay the process. Directly or indirectly, the land became tax-delinquent and was "bid to the state" at tax sales. By 1934 the state found itself in the landholding business to the extent of about three million acres, and had arrived at the conclusion that most of this land was unsuited to agricultural settlement. Wherever it was practicable, this land has been "blocked out" into state and national forests, state parks, game refuges, and public hunting grounds. The most important landscape quality which has resulted from this change to public ownership has been fire protection and reforestation, which has hastened the development of the new cover.[10]

There are still large areas of the cutover lands which are in private ownership. Some of this is in hunting and fishing clubs; some is used for other purposes, but much is held for speculation. A great share of the land in the second class seems destined for public ownership. In time, under protection, the wild lands will become forest lands, and the sandy soils will bear another crop of timber. In what manner this crop will be harvested may depend upon how time has changed public and official consciousness since the earlier harvest.

THE ORIGIN OF THE SETTLEMENT

The lumber industry moved into the High Plains without any preëxisting structure of occupance on the land. The camps were far from the sources of supplies, and food for the men and forage for the animals were costly. Local produce found a ready market and a high price.

There were among the lumberjacks many who had been farm boys, who knew how to cultivate and who knew the difference between the light dry sands and the heavier soils. It is probable that the better spots of soil were taken up first, but proximity to the scene of lumbering operations and to railroads must have been of equal importance in guiding the choice of land for homesteading.

Where the soil was favorable to the crops which were planted,

[10] From the inventory of some of these lands made by the Land Economic Survey of the Michigan Department of Conservation much of the basic material of this paper has been drawn.

especially in the southwestern parts of the area, the settlements spread from these nuclei as the land was cleared by logging (Pl. XLIII, Fig. 3). Pioneer farmers came in over the railroads until most of this southwestern area is now occupied by agriculture and forms one of the landscape types which make up the present expression of the High Plains (Pl. XLIV, Fig. 1).

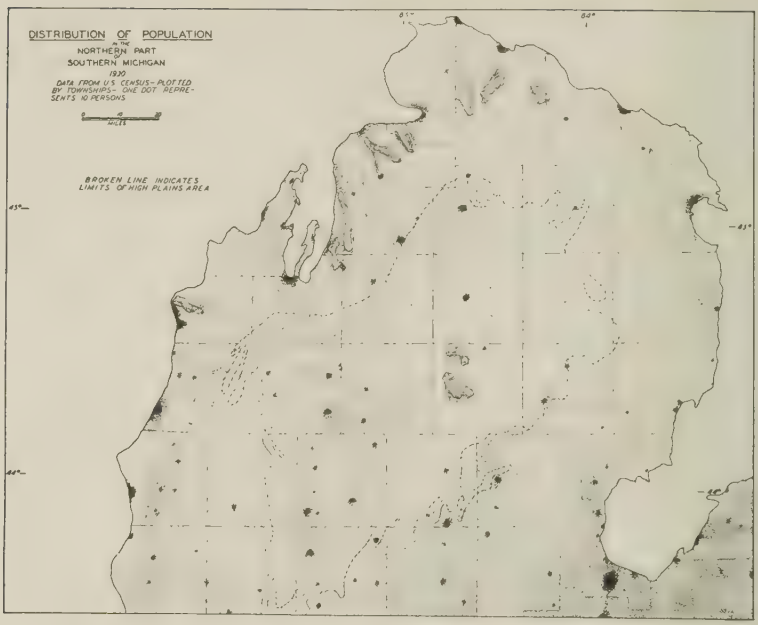
In the eastern parts of the area most of these "seeds of settlement" fell upon poorer soils and when the lumber camps with their high prices and ready markets moved away these settlements collapsed. There was a "wholesale abandonment of farms" in the pine country. In spite of "various intensive real-estate selling schemes" the land was not taken up, and it slowly reverted into wild land and into tax delinquency.

Wherever a mill was established along the railroads a nucleus of people grew up around it. From these agglomerations of the lumber industry can be traced the origins of almost all the towns in the High Plains. It was inevitable, perhaps, that most of these would disappear, since they were located with reference to available pine timber and to milling operations. The degree to which they have prospered and remained in the present landscapes of the High Plains probably is due to other, and then unforeseen, advantages of situation and to the concentration of supply function which they developed in the period of their existence as lumber towns. All of them have experienced a more or less rapid decline in population since the decade after the peak of lumber operations.

Many of these sawmill towns have been wrecked or burned and have vanished completely from the landscape. A great number exist as a few houses around a railroad station or a collection of weather-beaten shacks clustered around the foundations of a wrecked mill and surrounded by abandoned and unproductive fields. Even those towns and cities which grew to the greatest size and were the latest to decline are definitely falling from their peak populations.

III. THE PEOPLE AND THEIR COMMUNICATIONS

Even in its most favorable locations the density of the population on the High Plains does not equal that of the agricultural lands of southern Michigan. The most peculiar aspect of the distribution of this population is the variations in the patterns which it forms.


DISTRIBUTION OF POPULATION
IN THE
NORTHERN PART
OF
SOUTHERN MICHIGAN
1920
DATA FROM U.S. CENSUS - PLOTTED BY TOWNSHIPS - ONE DOT REPRESENTS 10 PERSONS
BROKEN LINE INDICATES LIMITS OF HIGH PLAINS AREA

Map 13

Spots which lack habitations are embedded in areas of relatively dense population, and there are wide expanses which are almost uninhabited.

THE POPULATION PATTERN

The pattern of the distribution of people in the northern part of the Southern Peninsula of Michigan is formed by the interspersion of areas of relatively dense population with areas of relatively sparse population (Map 13). Within this pattern there can be recognized in the most general way three relatively dense areas. The first of these is the northward extension of the agricultural area of southern Michigan, which reaches approximately to the latitude of Saginaw Bay. The second is the concentration in the fruit-growing and recreation district along the western shore. The third, which might be considered an extension of the first, is the agricultural districts of the south and west portions of the High Plains area.

This third division is in itself composed of two parts roughly divided by the Manistee River. South of this river the Michigan and the Interlobate moraines and their associated till plains are generally covered by agriculture (Pl. XLIV, Fig. 1). North of the river a narrow strip of population extends along the Port Huron moraine and some of its outwashes. The rest of the High Plains area is sparsely populated by widely separated, small concentrations localized by spots of good soil or other factors of situation. The area between these concentrations is unoccupied except for single dwellings, which are ordinarily hunting or fishing camps.

These gross features of the population pattern when examined in detail are found to be composed of subordinate patterns similarly composed of a design of lighter and denser settlement. Wherever detailed soil maps are available, these lacunae in the population patterns can be seen to coincide with areas of drier and more sandy soils. In the northward extension of the belt of denser population along the Port Huron moraine the lacunae in the population pattern do not always correspond to the poor soil areas. Here the settlement is later and not so successful as in the southern parts of the area, and its uneven distribution represents, perhaps, a peopling which has not been carried on far enough to adjust itself to soil differences (Pl. XLIV, Fig. 2).

In its larger aspects the pattern of population concentrations correlates in general with that of the areas of heavier and more productive soils, but this correlation does not exist in all places or in detail. The causal relationship between the soil and the population densities can be advanced only in the sense that some of the soil types were more successful than others in supporting the agriculture which the settlers brought into the area.

THE COURSE OF SETTLEMENT

Prior to the lumbering operations the southwestern parts of the High Plains, which are today the most populous, were heavily forested. The area was without railroads, and the settlements were small and scattered. The inhabitants were probably part-time farmers and primarily engaged in trading and trapping and in the small-scale lumbering prior to 1865. Settlement followed quickly after railroads had been built into the area and lumbering operations had

cleared much of the land. "The first settlers immigrated . . . from New York, Pennsylvania and Ohio, primarily to engage in lumbering and trading. Later as the country opened up many of them took up agricultural pursuits." [11] (See Pl. XLIII, Fig. 3.) The new settlers came in on the railroads and probably tied their communications by the lumber roads to the focal points of the mill towns.

During the earlier time of the settlement of the area, hardwood lumbering helped to support the pioneer farmers, providing winter work or additional cash income from the sale of logs from the farm woodlots. The population increased slowly up to the decade of 1910–20, but through all this time, the areas of lighter soils have not been taken up by agriculture. These remain embedded in the rather even dissemination of the habitations as sharply marked lacunae where forests take the place of fields.

In the northern belt of settlement, which extends along the Port Huron moraine north of the Manistee River, the lumbering was on a much less grand scale than in the mixed forests farther south. Here the cutting moved more slowly through the area. Agriculture was encouraged by the markets provided by the many small lumber camps. Not only did those employed in the cutting operate part-time farms but also there was a "marked influx of settlers." From 1880 to 1910 there was a fairly continuous increase in the number of farms and in the acreage of land improved, and this served to hide, statistically, a smaller and local, but equally steady, abandonment of farms as the lumber camps moved away. By 1910 most of the cutting was over; the newly cleared lands were no longer taken up for farms and the abandonment went steadily on. Many of the farmers have remained, perhaps from inertia or the lack of means to go elsewhere, and the crop systems have been changed to provide a greater degree of self-sufficiency. The area remains in the landscapes of the High Plains as a district of going, if unremunerative, agriculture (Pl. XLIV, Fig. 2).

The correlation of the distribution of the population with the distribution of the other landscape-forming elements must be approached on a basis different from those which have earlier been stated as existing between the facts of the fundament. The facts of the fundament set broad limits to the forms of the occupance; cer-

[11] Wildermuth, R., and Fonder, J. F., *Soil Survey of Mecosta County, Michigan*, U. S. Dept. Agric., Bur. Chem. and Soils, Series 1927, No. 18, p. 2.

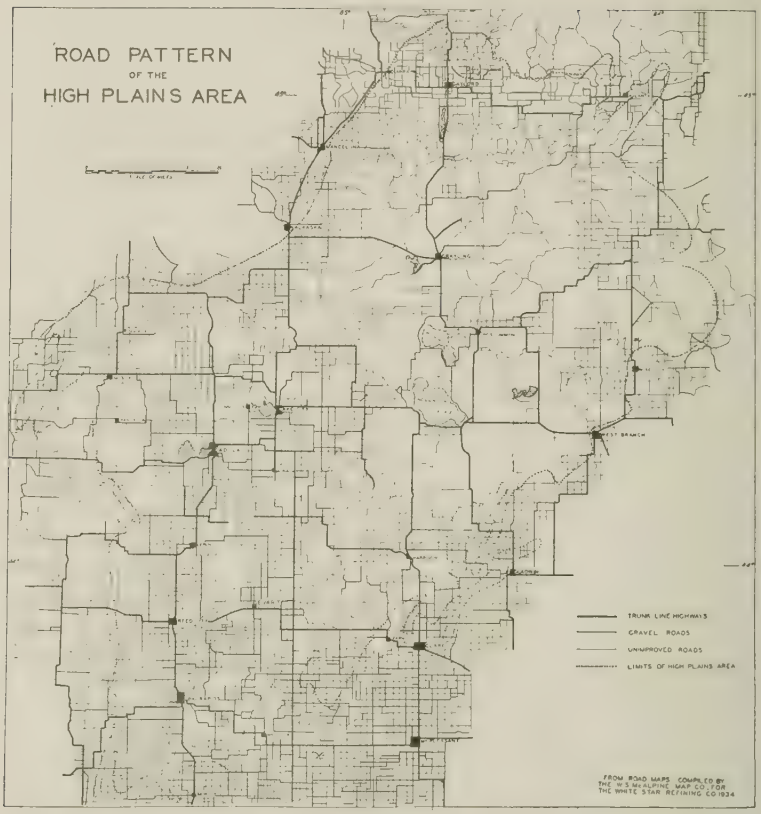
tain environmental complexes are unsuited to the culture which people inherit, making certain types of occupance economically impossible or unprofitable and hence temporary. Within the limits of the economic possibility cultural forms are solely the results of human actions, and their distribution is a function of their history. The distribution of the population concentrations in the High Plains is the present aspect of human progress in settling the area.

THE PATTERN OF CIRCULATION

The system of communication binds together the features of the cultural landscape. In an area of Occidental settlement every form which is functional has a path which connects it with the rest of the occupance. The lanes which connect the fields with the farmhouses, the rural roads which connect the farms with the towns, and the highways and railroads which connect the towns with the rest of the world are all aspects of the pattern of circulation. In the High Plains the evolution of the communication system parallels the sequence of occupance.

When the lumbering industry moved out of the High Plains it left behind the transportation system which it had built. The main railroads continued operations as through carriers and to serve the communities which had developed around the mills. The country away from the main lines was traversed by a network of logging roads and the grades of dismantled railroads, which were in excellent condition and which gave access to all parts of the area. Over the districts which were not at once taken up by agriculture, this road system was adequate for the horse-and-wagon transportation of the decades following lumbering, and is still the only way for communication over large tracts of the wild lands. Where traffic was somewhat heavier, parts of this system of lumber roads were taken over as "county roads" and improved by cutting back the brush and building more permanent bridges. On the map of road pattern (Map 14) these meandering ways can be seen leading through the unsettled northeastern parts of the High Plains.

Where agriculture took over the land, the lumber trails were speedily replaced by the familiar pattern of right-angled roads, which is a part of the culture of the people who occupied the land. A strip along each section line wide enough for a road was claimed by the township government, and it built the roads along this in-



Map 14

stead of acquiring other right-of-way. In districts where land has been abandoned or where settlement was planned but did not take root, this right-angled pattern remains as the skeleton of an occupance which failed, a straight, rutted, sandy trail enclosing the four sides of a square mile which differs not a bit from all the surrounding wild land.

The advent of automobile transportation introduced the highway into the system of communications. After twenty years of use the roads of the agricultural districts had become improved by widening and grading. A little surfacing solved the automobile problem in

these areas. Along the old lumber trails in the wild lands, now somewhat overgrown by "fireweed" brush, it was a different story, and pioneer motorists still tell of their adventures of driving through this wilderness in the none too reliable cars of the early days. For each one of these roads which goes somewhere there are ten which go nowhere. They divide, cross, and unite in a maze which puzzles the strange motorist as it must have puzzled the driver of the high-wheeled cart fifty years ago. The traveler is never sure whether he is on the road or on one of its multitudinous branches or, indeed, on any trail at all. Until the time of the state trunk-line highway system such roads were the ways across the plains.

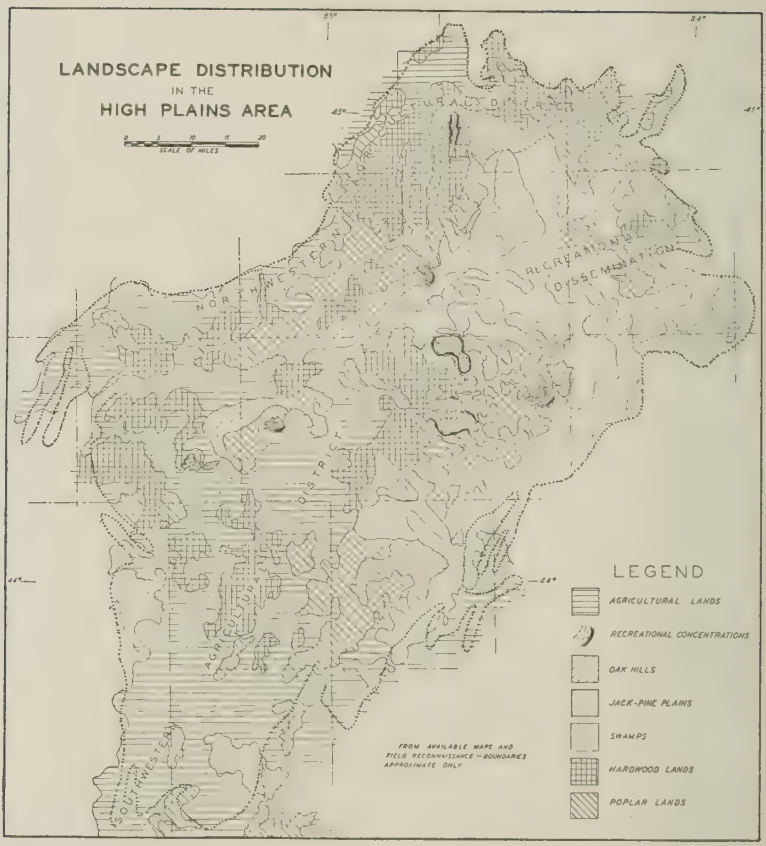
The trunk-line highway system is primarily intended to provide a means of getting from one place to another, not of facilitating the internal circulation of any particular area. It traverses the High Plains from north to south and from east to west with hard-surfaced roads in a large-scale replica of the right-angled pattern. In detail, however, the pattern is modified to provide for fast traffic; the sharp turns and corners are avoided by smooth curves made at the expense of acquiring a new right-of-way, and certain sections are entirely rebuilt to avoid other conditions.

The road pattern of the High Plains expresses the three modes of occupance which have marked its history: the windings of the lumber trails, the right angles of the agricultural districts, and the smooth, hard surfaces of the tourist highways.

IV. THE LANDSCAPES OF THE HIGH PLAINS

It might be expected from the diversity of the soils, surface forms, and drainage conditions of the High Plains that the landscapes which express the combination of these elements would be of endless diversification. However, such has not proved to be the fact; the elements combine into relatively few types of landscapes, and the complexity of the landscape pattern (Map 15) results from the interspersion rather than from the large number of these types. It is similar to a complicated mosaic made from a few kinds of tiles.

The landscapes of the High Plains fall into two general classes. The first is characterized by continuous human occupation, the agricultural, recreational, and urban landscapes; the second, by the



Map 15

areas unoccupied by men, which, for want of a better collective term, are here called the wild landscapes.

THE CULTURAL LANDSCAPES

The pattern of settlement in the High Plains is composed of three types of occupance. The first of these, the agricultural landscapes, is made up of the southwestern and the northwestern agricultural districts and the scattered agricultural settlements in the

other parts of the area. The second, the recreational landscapes, is composed of the recreational agglomerations and the disseminated recreational occupance. The third, the urban landscapes, includes the cities, towns, and villages.

THE AGRICULTURAL LANDS

The distribution of the present agricultural lands in the High Plains corresponds in general with the distribution of the original broadleaf or mixed pine and broadleaf forests (Map 15). They occupy the well-drained till plains, the more loamy moraines, and some of the heavier outwashes of the western and southern parts of the area. The three entities which compose the agricultural lands, the southwestern district, the northwestern district, and the scattered agricultural settlements, are differentiated not so much by the variations in character of the farms or the crop systems as by the nature of the distribution of the farms in relation to the district and to the High Plains as a whole.

THE SOUTHWESTERN AGRICULTURAL DISTRICT

From the Manistee River southward the Michigan and the Interlobate moraines and their associated till plains are generally covered by continuous agriculture (Map 15). Although a considerable portion of the land remains in second-growth woodlots, much is uncleared of stumps, and abandoned fields are common, still farm borders on farm and cultivated fields are the most characteristic expression of the landscape.

This area of continuous agriculture is bound together by a right-angled pattern of well-graveled roads, which mark almost every section line. From these the farmsteads are set back a little distance, generally shaded in a small grove of trees, above which a windmill and the top of a silo may stand out. The fields are laid out along the survey lines in precise rectangles of ten or twenty acres, giving the landscape an orderly appearance quite in contrast with the knob-and-basin surface of the moraine (Pl. XLIV, Fig. 1).

When examined in detail, this agricultural landscape is found to be made up of continuous small farms of 120 acres or less. Each of these farms is itself composed of three kinds of land: cropland, pasture land, and woodland, all bound together and connected as a functioning whole by the farm lanes to the nerve center of the

farmyard with its buildings. Not every farm has all these kinds of land, but collectively they make up the agricultural landscape.

Ordinarily a third to a half of the farm land is used for crops. Of this, 5 to 15 per cent is in potatoes, 30 to 50 per cent in hay, and 30 to 40 per cent in grains.[12] From one to two thirds of the farm is in pasture, some of which is uncleared stump land, some wet land, and some abandoned fields. The pasture land, in general, composes that which appears unprofitable to put into crops, or which has been cropped and abandoned. The woodland is potential agricultural land which has been left in woods because of the value of the product in the economy of the farm. Commonly the woodlots are located on the crest of knolls or other steep slopes which would not make good cropland, but they are also seen on the intermediate slopes or level land. Perhaps in the evolution of the agricultural landscape the woodlots were left where the timber was the best and the fields and pastures where the clearing by lumbering was most complete. The nerve center of the farm is the farmyard. Here is the junction point between the lanes which connect the fields and the road system which ties the farm with the rest of the countryside.

The southwestern district is the most completely settled and agriculturally prosperous of the parts of the High Plains. The localization of this district must be attributed to the loaminess and the retentive character of the soil material derived from the Michigan lobe of the glacier. The soil itself did not induce the agriculture, but it was the kind of soil upon which the agricultural practices of the settlers produced enough returns to enable them to continue to cultivate it.

THE NORTHWESTERN AGRICULTURAL DISTRICT

North of the Manistee River the Port Huron moraine and some of its outwashes form a long narrow district of agricultural settlement reaching as far as Montmorency County on the east side of the High Plains (Map 15). Within this district the individual farms and their practices are much like those of the southwestern area, but the pattern of these farms in the landscape is different. Instead

[12] Hill, E. B., Riddell, F. T., and Elliott, F. F., *Types of Farming in Michigan*, Agricultural Experiment Station, Michigan State College, Spec. Bull. No. 206, p. 69. Lansing, 1930.

of a continuous area of farm bordering on farm, the northwestern district is composed of areas of farm land separated by areas of uncultivated land (Pl. XLIV, Fig. 2).

The unsettled parts of the northwestern district cannot be correlated with poor soil distribution, as in the southwestern district. The agricultural settlement of the northwestern district followed after the later lumbering of the broadleaf forests and ceased to expand to newly cleared areas when the lumbering declined between 1910 and 1920. The result was the impression on the land of an early pattern of settlement, arrested in expansion and adjustment by the collapse of the economic support of lumbering.

THE ISOLATED AGRICULTURAL SETTLEMENTS

Scattered over the eastern and central parts of the High Plains are small patches of heavier soils, in some cases small till plains, in others, heavier clayey places in the moraines. Many of these bear isolated agricultural settlements.

Some of these, undoubtedly, were settled to supply the lumber camps with products, others by the hopeful immigrants of the "land-boom" days. Once pioneers of the advancing agricultural front, these settlements have become relicts by the abandonment which has gone on around them. Their size is limited by the extent of the arable soil and, because of small population, the cost of community functions and connections with the rest of the world is high. They persist in the landscape, however, probably in a slowly declining status.

THE RECREATIONAL LANDSCAPES

The cultural landscapes of the second type are those which result from recreational occupance. Though the recreational population is seasonal, the forms which it makes are permanent, and these are a significant addition to the cultural landscapes.

Just as the agricultural landscapes are distributed in accordance with parts of the soil pattern, so the recreational landscapes are associated with parts of the drainage pattern. The values which are usually paramount in the selection of recreational locations are the presence of woods and waters, but the presence of established facilities, congenial neighbors, and ease of access also represent attractions.

The landscape quality which results from recreational occupance varies with the type of recreation sought for. In general, two classes can be recognized: the resort type or agglomerated recreational occupance, and the hunting and fishing type or the disseminated recreational occupance. The first of these occupies little total area, but produces such conspicuous forms as summer hotels, cottage villages, and golf courses. The second occupies much larger areas, but produces inconspicuous forms; the cabin and the clubhouse are lost in their surrounding wild land, and the persons who inhabit them seek seclusion rather than company (Pl. XLIV, Fig. 3).

In the High Plains there are three areas of recreational agglomeration at the three largest lakes, Houghton, Higgins, and Otsego, and several smaller areas on lesser lakes (Map 15). The disseminated recreational occupance is scattered over the northeastern parts of the area, where the lack of agriculture and the abundance of wild land furnish the necessary basic conditions, and where land values are so low that both public and private agencies may own tracts of land large enough for recreational use.

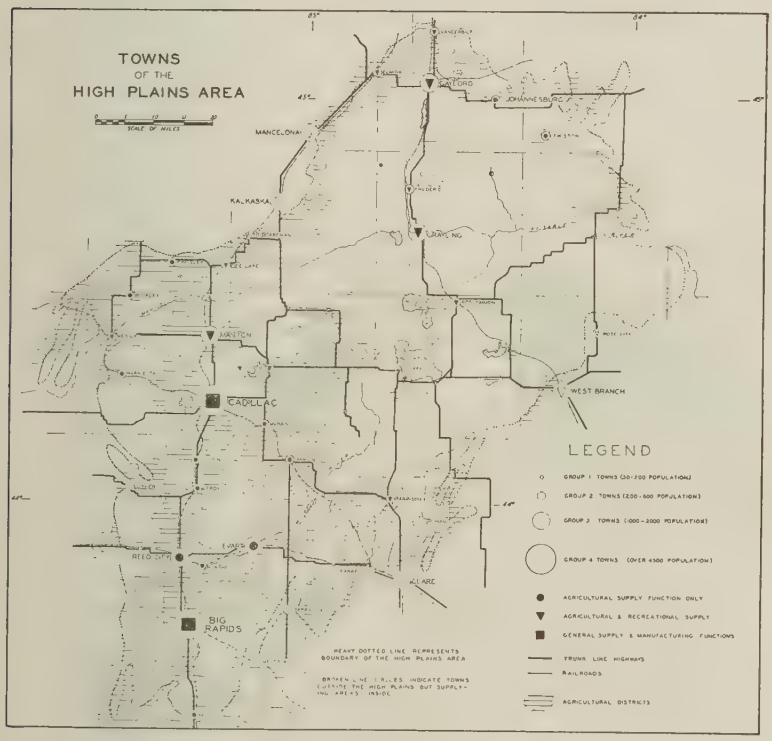
THE URBAN LANDSCAPES

As stated earlier, the urban agglomerations of the High Plains had their origin in the mill towns of the lumbering times. More or less rapidly all of them reached a peak of population from which they are now declining. A few of the larger cities developed wood-using industries, which extended their functional importance beyond the limits of their immediate trade territories and prolonged their period of growth almost up to the present.

From the viewpoint of distribution, those towns which survive in a functional sense are those in situations which contained advantages beyond the presence of timber and mills. Of the forty-three towns which are here considered functional, twenty-two are in the southwestern agricultural district, eleven in the northwestern agricultural district, seven on lakes and streams serving recreational concentrations, and the remaining three on main trunk-line highways and close to scattered farming districts (Map 16). Approximately 30,000 town dwellers live in the agricultural districts, 700 in the resort villages, and 2,800 in the three trunk-line towns.

The scope of this paper does not permit descriptions of the morphology and the history of the towns of the area. In general, all

of them originated from economic conditions no longer present, and the number of towns and the town population seem overlarge for the agricultural and industrial position of the area. This is apparent not only from the present condition of most of the towns, but also from their history. Of those which once existed more than half have dis-



Map 16

appeared completely or have been reduced to functional insignificance. Those which do survive are in various stages of a course of decadence, which, from the viewpoint of the present, will result in the extinction of many and the reduction of the rest till their populations are only sufficient to take care of supplying what will remain of a shrinking agricultural umland.

THE WILD LANDSCAPES

The landscapes so far described have been characterized by cultural forms. They have their principal distribution in the western and southern parts of the High Plains. The second group of landscapes lack the cultural forms: these are the wild landscapes which have their principal distribution in the northeastern part of the area. They are named after the cover type, which is the most easily recognizable feature of the landscape, but they should be regarded as representing the combination of soil, surface, and cover as a distinctive landscape complex.

THE OAK HILLS

The surface of the sandy morainic uplands of the east and central parts of the High Plains area consists of a few forms endlessly repeated (Pl. XLV, Fig. 1). Smooth, rounded slopes are surmounted by low knolls and separated by flat-floored, sand-filled, streamless valleys. The diversification of the surface is offset by the uniformity of the vegetation, for the low, clumpy growth of oak covers the knobs and basins, valleys, and slopes in a mantle of dusty green. Through the oak one may catch a glimpse of the white trunks of birches and the lighter green of a grove of poplars and, here and there, a single maple or fire cherry, but these serve only to emphasize the dominance of the oak. The sandy soil beneath this forest is thinly covered with a brown-green carpet of bracken, sweet fern, and low blueberry bushes thickset with the stumps of pine now charred and rotting. In some places the straight, clean trunk of a single pine stretches up through the foliage of the oaks to support its crown above the ceiling of the common forest.

At some places the straight concrete roads of the trunk-line highway system cut through the hills, but more commonly the meandering double sandy trails of the old lumber roads are the only means of communication. Along these roads one may see widely separated old farmsteads, many of which are abandoned and a few reoccupied. The forlorn houses with gaping windows and sagging doors stand as relicts of agricultural settlement which failed upon the soil of the hills (Pl. XLIII, Fig. 4).

The passing seasons bring one brief period of brilliant beauty to the oak hills. The sharp frosts of the first weeks of October change the green mantle to a coat of many colors which, when seen from

a short distance, belittles an attempt to describe it. Against the heather-colored background of the bracken, the oaks hang the scarlet of their leaves. Interspersed in the setting are the flaming reds and crimsons of the fire cherries and the maples. The brilliant flickering yellow of the poplar leaves as they twinkle in the sun add a shimmer to the colorful landscape. This brilliancy lasts but a few days; the oak leaves turn to a dull, dry brown and cling stubbornly to the trees; the others fall and are covered by the first snows, which presage the long, cold winter.

The oak hill landscapes are distributed along the moraines which form the eastern boundary of the High Plains and on the moraines which connect the Michigan with the West Branch chains (Map 15).

THE JACK-PINE PLAINS

An almost imperceptible descent leads from the oak hills to the jack-pine plains. The smooth slopes from the knobby surface flatten out into a level, sandy plain covered with a somewhat open forest of ungraceful jack pines (Pl. XLV, Fig. 2). In some places the trees are in dense clumps, but ordinarily the forest is parklike; the vision penetrates for two or three hundred yards until it is finally stopped by the trunks. The floor of this open forest is covered with a dull brown growth of bracken, sedges, and sweet fern lying thinly over sand strewn with pine needles. Almost everywhere are the marks of past fires; splintered stubs, still firmly rooted, point a single, blackened finger upward; others, slowly rotting, lie half buried in the sand. The soil beneath the needles is a grayish yellow sand, dry and infertile, with whatever humus it had accumulated in ten thousand years of forest growth burned out in a few decades of fires.

Except for the network of the old lumber trails, cultural forms are almost lacking in the jack-pine landscape. After fifty years of disuse these trails still are visible and are the only communications which lead, or mislead, the rare traveler over the plains.

The jack-pine plains bloom but once a year. The water from the melting snow is absorbed by the porous sand, and for a few weeks the soil is moist. Then the quick-growing flowers of the plains make their brief appearance. Among the clumps of grass and stalks of fern the varying blues of the birdfoot violets tint the ground. Delicate anemones dot the needle-strewn soil, and the spikes of the early-blooming toadflax rise among the taller shrubs. With the hot days

of late June the plains are again dry. The flowers and the grasses shrivel, and only the bracken and the fern remain on the forest floor as a carpet for the jack pines which, with their unchanging green and ungainly form, dominate this landscape from season to season.

The jack-pine plains are distributed over most of the dry sandy outwashes in the central and the northeastern parts of the High Plains (Map 15). They are complementary to the oak hills in occupying the poorer soils formed from the material deposited by the Saginaw lobe of the glacier.

THE HARDWOOD LANDS

In contrast to the sunny oak and jack-pine woods, the forests of the broadleaf trees are shady and damp. Through the canopy of the foliage the sun reaches the forest floor only in single beams which flicker as the wind stirs the leaves. The forest panorama is one of rather widely and evenly spaced trunks rising from a floor covered with seedlings and reaching upward to a ceiling in which the foliage of the individual trees is almost indistinguishably blended into the general canopy.

From this description of a virgin wood of broadleaf trees the landscape group here called the hardwood lands varies widely. If the forest has been thinned by cutting, it has a more open and ragged appearance and the sun shines through, lighting up the forest floor strewn with the litter from the cutting. If the lumbering operations have been extensively carried out, the forest is gone, and in its place has grown up a low, heavy, brushy growth of the reproduction of the original species mixed with poplars and fire cherries (Pl. XLV, Fig. 3), above which remain the few trees of the original stand left by the lumbermen. The original forests were in various stages of progression from the pines toward the broadleaf trees and were also edaphically differentiated between the beech–maple type on the drier soils and the elm–ash–red maple on the more moist soils. This fact, combined with the addition of the quick-growing trees which have come in since lumbering, have made the hardwood lands anything but a homogeneous landscape type. In a more detailed study the variations of this type would necessarily be recognized, but for the sake of clarity they are here lumped together, in spite of the very apparent differences which do exist.

The patchy distribution of the hardwood lands (Map 15) must

be regarded as the remnants of a much larger distribution which once occupied most of the western part of the High Plains. The agricultural landscapes and the hardwood lands occupy the heavier and more retentive soils formed from the material deposited by the Michigan lobe of the glacier.

SWAMPS

From a distance there is a great deal of symmetry and grace to a swamp. This aspect is gained from the compact conical shape of the smaller spruces and the spirelike tops of the taller ones (Pl. XLV, Fig. 4). Inside the swamp this grace and symmetry are lost. The forest floor is littered with fallen trunks, mossy and covered with fungus, and from it comes the heavy, damp odor of decaying vegetation. On this floor the trees are thickly set with their crowns forming a cover so dense that the swamp is always gloomy. Trees uprooted from the soil have fallen and lodged against others and, as the wind blows through the swamp, these creak ominously.

At the edge of the woods is a narrow fringe of alders and willows between the forest and the grass marsh in its center. Here the sharp-edged sedge grows upon a floating bog which springs at every step. If one ventures out too far he may be in the water before he reaches the pond. Where the swamps have been cut over and burned the alder-willow brush has grown into dense thickets, forming almost impassable tangles.

The distribution of the swamps is in reference to the detailed, not the chorographical, order of things in the High Plains. They are found along river channels, but not along all river channels. Their place in the major lineaments of the area is sporadic, not invariable, as are those of the oak hills and the jack-pine plains. Oak hills are where they ought to be in accordance with the pattern of the surface and the soils; swamps are where one finds them.

THE POPLAR LANDS

A poplar thicket is a bright and pleasant spot. The light color of the bark of the trees and the fresh green of their leaves, together with the slender, graceful symmetry of the trunks, make an attractive contrast with the dusty oaks and the harsh, dry pines. Even if the trees are close together the foliage is seldom dense enough to shut out the sunlight. On the forest floor is a thick carpet of dry

brown leaves which crackle underfoot and over which the foliage casts a changing pattern of light and shadow as they twist and turn in the slightest breeze.

The most cosmopolitan of all the trees in the High Plains is the poplar, with its companion, the birch. These two form an association which perhaps covers as much area as any other, and, furthermore, the poplar is ubiquitous in almost every one of the other forest types. The poplar seeds are blown widely by the wind, and the broad tolerance of soils and the quick-growing quality of the tree have enabled it to gain a foothold and outstrip the reproduction of the broadleaf trees and the pines. Nevertheless it is a poor competitor, and in three or four decades the other growth forces out the poplar and becomes the dominant tree. The poplar is the pioneer which rushes into new areas left by clearing or burning, but when the land becomes more settled, so to speak, by more persistent trees, the poplar dies away, to be found again on another frontier.

It is not possible to characterize any particular part of the large area dominated by the poplars as a poplar landscape in the same sense as the landscapes which have been previously described. These latter are permanent combinations of characteristic soil and surface as well as cover, while the poplars are a temporary or transitional vegetation, a scab tissue which covers the wounds of cutting and burning until the permanent cover developing underneath forces them out.

The regions of the most extensive distribution of the poplar lands in the High Plains are the more moist outwash sands of the eastern parts, where they are being supplanted by the jack pines, and the areas of recent hardwood lumbering, where they shade the reproduction of the original species which will eventually take their place in the landscape.

THE PATTERN OF THE LANDSCAPES

The pattern formed by the distribution of the various landscapes which collectively make up the geographic expression of the High Plains is shaped by the same master lines which can be seen in the distribution of the elements of surface, drainage, and soil (Map 15). In general, those areas originating from the material deposited by the western lobe of the glacier are characterized by the cultural landscapes and the hardwood lands; those from material laid down by the eastern lobe, by the wild landscapes: the oak hills, the jack-

pine plains, and the swamps. To this generalization there are many specific exceptions, landscapes which are not where they should be according to the scheme of things.

V. CONCLUSION

The position of the High Plains upon the patterns of the world distributions of climate, vegetation, and population undoubtedly underlies the broader facts of its geography, but these larger distributions neither mark the regionality of the area nor orient its internal differentiation. As the study presented here has attempted to show: *The distribution of the landscape-forming elements and the resulting landscapes follow in general a fundamental pattern based upon a distribution of the surface features and soil materials which were laid down by the retreating ice of the latest glaciation.*

Upon this original fundament the weathering of the glacial material into soils and the development of the cover types proceeded in a direction consistent with the existing climate. Until the time of the occupance of the lumbermen this process of landscape development had gone ahead almost to the harmonious codistribution of cover associations and soil types. Thus far the activities of man had not altered the nature of things in the High Plains to any significant degree, but a new occupance took over the area, changed the cover, introduced new elements into the course of development, and initiated the modern landscapes.

Into the slow and orderly process of the evolution of the natural landscapes were thrust new cultural factors: clearing, fire, and agriculture. The result was an almost complete change in the cover associations and the introduction of new types in one way or another suited to survive in the new régime. The basic framework of the soil and the surface remained practically unaltered.

From the débris of this overturn the modern landscapes are taking form. Slowly they can be seen to emerge as an image develops upon a photographic plate. Although their outlines are not yet sharp and their details are obscured by the "fireweed" associations and by the ebb and flow of human adjustment, nevertheless their distribution is apparent and it is seen to follow the same fundamental pattern of the surface and the soil.

University of Michigan

PLATES XLIII–XLV

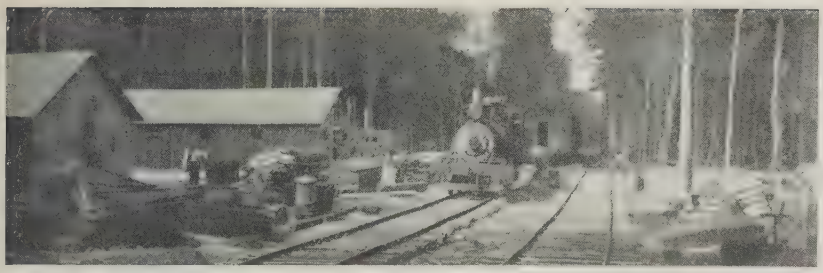


FIG. 1. A lumbering railroad

FIG. 2. Landscape after burning

FIG. 3. A pioneer farm

FIG. 4. An abandoned farm

Photographs by the Michigan Department of Conservation

FIG. 1. The southwestern agricultural district

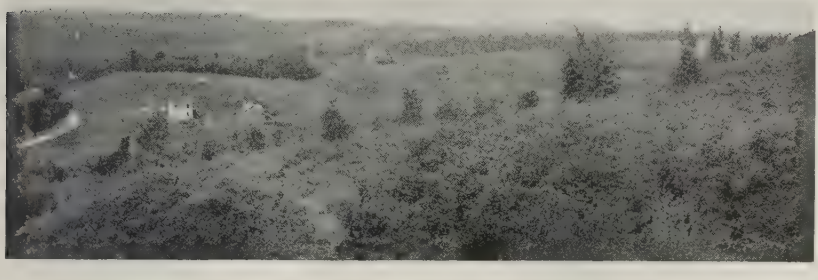


FIG. 2. The northwestern agricultural district

FIG. 3. A fishing cabin

FIG. 4. A town which survived from the lumbering days

Photographs by the Michigan Department of Conservation

FIG. 1. The oak hills

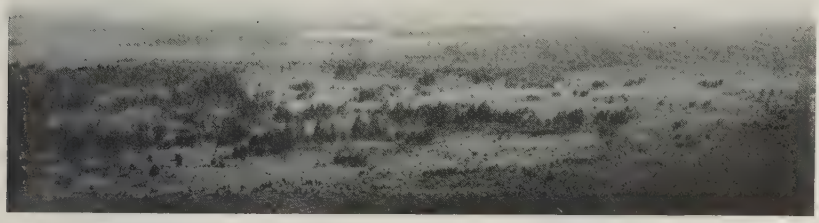


FIG. 2. The jack-pine plains

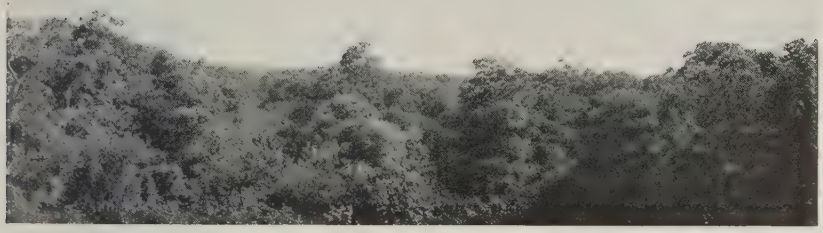


FIG. 3. The hardwood lands

FIG. 4. A swamp

Photographs by the Michigan Department of Conservation

POPULATION REGIONS OF THE UNITED STATES

STANLEY D. DODGE

INTRODUCTION

Summary of method

THE counties of the United States have been classified in this study in terms of the percentage of decline which the population figures for 1930 represent in relation to the highest figures at any previous census.[1] In the classification of the counties for distribution on a county base map of the United States the following categories are employed:

A. Decade-to-decade increases;

B. Decline from peak less than 25 per cent;

C. Decline from peak more than 25 per cent and less than 50 per cent;

D. Decline from peak more than 50 per cent;

E. Unclassifiable, usually representing population of extreme irregularity in decade-to-decade numbers.[2]

Areas of population decline in the United States

The results of the distribution of categories of population decline by counties on a map of the United States are shown in Map 17. Concentrations of areas of decline of from less than 25 per cent to not more than 50 per cent (Categories B and C) appear notably in the Corn Belt, with a few counties of greater decline in northern Mich-

[1] I am indebted especially to Messrs. Harrison V. Chase and Merritt W. Johnston for aid in tabulating, classifying, and mapping the census data involved in this study, and to Mr. John B. Pope for preparation of the final maps.

[2] This category was necessary in the classification of the townships of New England. See Dodge, Stanley D., "A Study of Population in Vermont and New Hampshire," *Pap. Mich. Acad. Sci., Arts and Letters*, 18 (1932): 131–136. 1933. In the study by counties only Yellowstone Park actually falls in Category E.

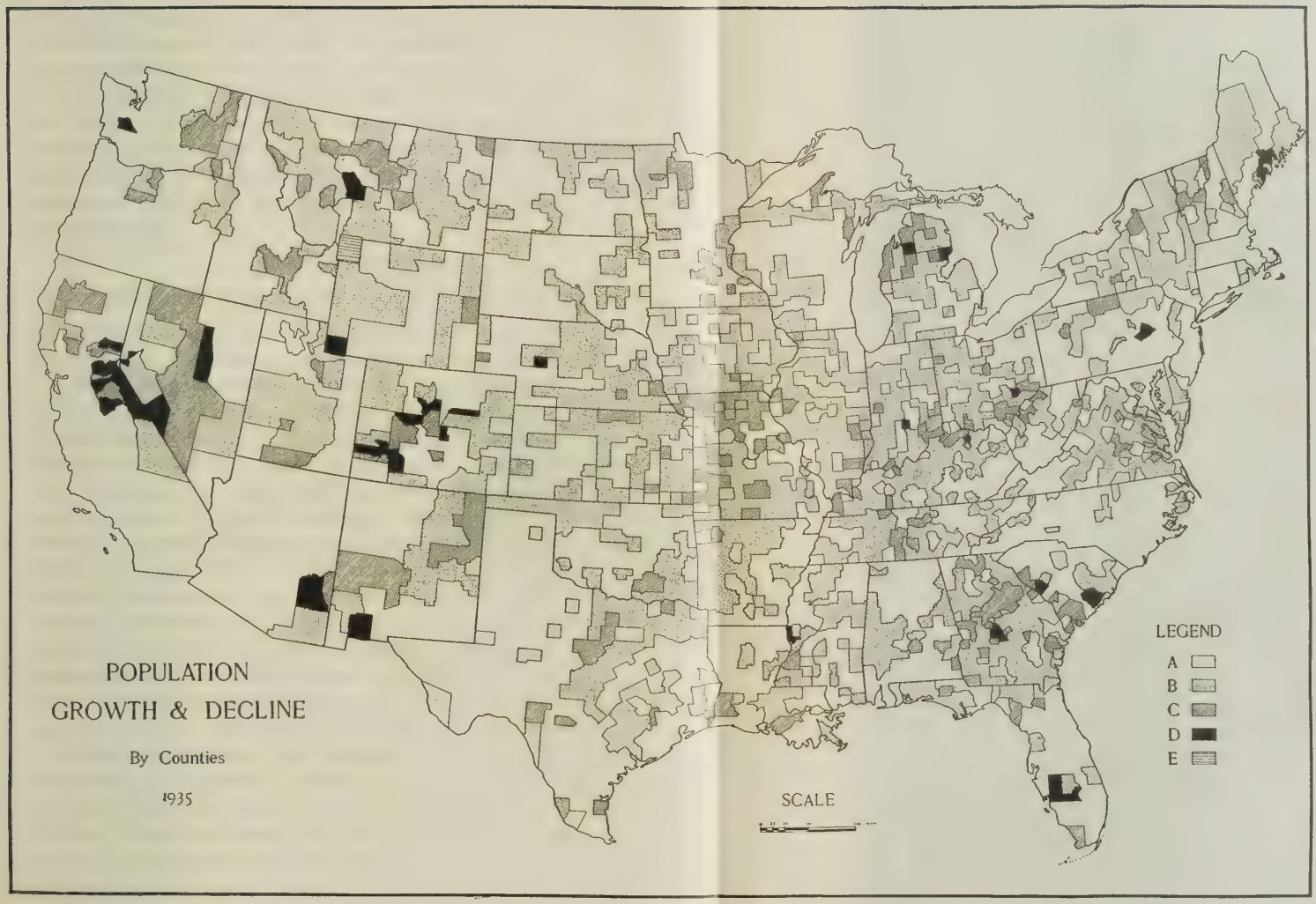
igan, in the Ohio Valley, and in a belt from southern Iowa through Missouri. Other areas of special interest occur in eastern Virginia, in Piedmont Georgia, and in Montana and eastern Washington, northwestern Arkansas, and from southeastern Oklahoma to central Texas. Groups of counties with decline running generally from more than 25 per cent to more than 50 per cent (Categories C and D) lie in central Colorado, in a belt from northeastern New Mexico to southeastern Arizona, and in Nevada and eastern California.

Difficulties involved in using county basis

The reliability of the data here presented is somewhat vitiated by the use of so large a base as the county. In many areas the counties are of such great size that reliable conclusions cannot be drawn from them. In New England, for example, the investigation of population decline on a township basis shows that there has been decline of more than 50 per cent for township after township in a broad belt running through the central part of the area from eastern Maine to western Vermont, Massachusetts, and Connecticut.[3] On the county basis this same area stands out as still growing, for the most part, because the counties are larger than the average for the eastern United States, and because there are, locally, townships the population growth of which has been of a magnitude sufficient to offset the decline in the other parts of the county. Only Waldo and Lincoln counties, in Maine, suggest the true state of affairs in the greater part of the area of decline. On the other hand, the counties of the northern part of the Southern Peninsula of Michigan show on the map (Map 17) a close approximation to the conditions of population decline as indicated when the distribution is by townships.[4] For these reasons the county basis is considered unsatisfactory, but nevertheless this distribution of the categories of population decline does have a certain usefulness. In the New England area the decline of certain townships is masked by the continued population growth of local areas within the counties, and in general throughout these six northeasternmost states centers which have continued to grow are articulated well with the present transportation systems. Townships of which the village centers lack

[3] Dodge, Stanley D., "A Study of Population Regions in New England on a New Basis," *Ann. Assoc. Am. Geographers*, 25 (4) : 197–210. 1935.

[4] Dodge, Stanley D., "Population Regions of the Southern Peninsula of Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 19 (1933) : 345–348. 1934. See especially the map on page 346.



MAP 17

A. Decade-to-decade increases
B. Decline from peak less than 25 per cent
C. Decline from peak more than 25 per cent and less than 50 per cent
D. Decline from peak more than 50 per cent
E. Unclassifiable, usually representing population of extreme irregularity in decade-to-decade numbers

complete articulation are the ones which have declined. When, therefore, throughout the United States whole counties are found which show considerable decline, the conclusion is that the "center" has not stood up well in the face of the economic vicissitudes of the period since the beginning of the decline, and that this failure is somehow related to changes in the delicate balance of economy among resources, markets, and people. These ideas are expanded below for specific regions. All that the county base does is to point to rather large areas which have been affected. Analysis requires a finer mesh of distribution.

SPECIAL PROBLEMS

Investigation of decline by dates of incidence of decline

The distribution of categories of population decline reveals merely those areas in which special problems may exist. Decline of population, without compensating curtailment of governmental machinery, has in many places created problems of local administration, difficult to adjust and requiring further study from the point of view of the political scientist, if a proper solution is to be arrived at and if the *ad hoc* readjustment which may be forced ultimately is not to bring as a consequence untold hardship to the people most intimately affected. In areas of decline problems of marketing arise, problems of the local adjustment of the resources to the current national economy, the solution of which cannot be reached without more thorough investigation. Decline of population brings in its train a whole sequence of changes in the cultural landscape, in the realm of geography itself, and a rearrangement of certain fundamental aspects of the landscape, such as the regrowth of the "natural" vegetation and the invasion of species of wild animals locally extinct.

In the investigation of the incidence of decline the distribution of dates of the culmination of population numbers opens up a new line of study which may lead to a deeper understanding of the causes of decline. When large areas are affected simultaneously, concurrent economic change may be shown to have had an effect. Examples of this will be given below.

When population maxima of a given date are found to be grouped in a striking way, the reinvestigation of the population curves of adjacent areas may reveal submaxima, peaks of lesser magnitude, and in this way various irregularities in the population curve may be

studied. In parts of Virginia, for example, population was declining at the epoch of the first census, but recovered and reached a maximum a few decades prior to the Civil War, only to decline again, and recover again. Table I gives data for Frederick and Gloucester counties, with the peaks emphasized.

TABLE I

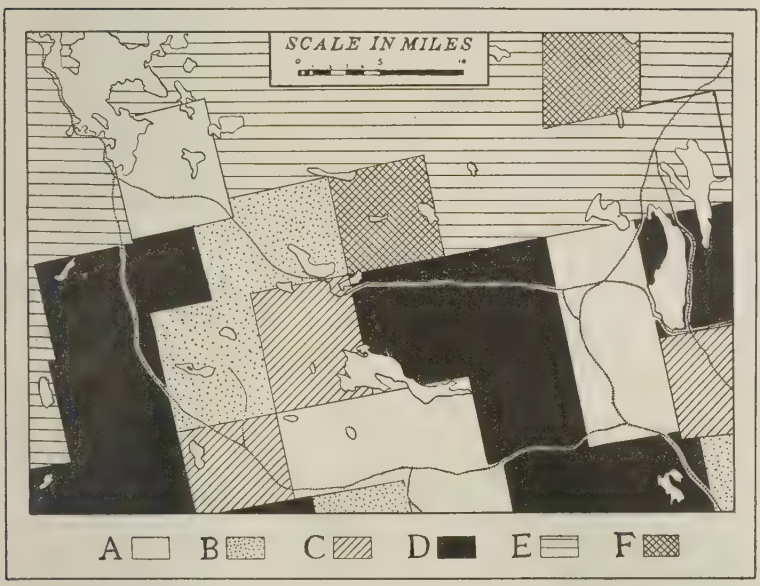
POPULATION FIGURES FOR FREDERICK AND GLOUCESTER COUNTIES, 1790 TO 1930

Census year	*Frederick County*	*Gloucester County*	*Census year*	*Frederick County*	*Gloucester County*
1790	19,681	13,498	1870	16,596	10,211
1800	**24,744**	8,181	1880	**17,553**	**11,876**
1810	22,574	**10,426**	1890	12,684	11,653
1820	24,706	9,678	1900	**13,239**	**12,832**
1830	**26,046**	10,608	1910	12,787	12,477
1840	14,242	**10,715**	1920	12,461	11,894
1850	15,975	10,527	1930	**13,167**	11,019
1860	16,546	**10,956**			

Significance of continued growth and integration with the current economy

The areas which have been able not only to maintain population but also to have continued growth of population are, even in detail, those which are integrated most completely with the highway and railway systems, in short, with the road system, using that term to cover the whole geographical aspect of circulation.[5] Locally, even when they are surrounded by areas of marked decline (Category D), townships in New England have increased in population, and they are found to be on the principal roads, usually at junctions of highways or railways (Map 18). The detailed investigation of population decline in the Southern Peninsula of Michigan [6] shows that the counties of which decline of more than 50 per cent is characteristic have embedded within their combined areas places of less decline. These small areas are centers which are linked with the road system of the state more thoroughly than are the villages and hamlets of the surrounding areas. This condition is comparable to that of continued growth within areas of decline which characterizes New England; it is a difference of degree, but not of essence. For the United States

[5] Brunhes, J., *La Géographie humaine* (Paris, 1925), pp. 62–63.
[6] Dodge, *loc. cit.*



MAP 18. Central Maine, southeast of Moosehead Lake (upper left), showing the relation of continued growth to the main lines of the transportation system

A. Still growing
B. Decline less than 25 per cent
C. Decline 25 per cent to 50 per cent
D. Decline more than 50 per cent
E. Unclassifiable, with small numbers of people at some census dates
F. Areas without population at any census

as a whole the investigation on the county basis shows similar results. The counties which are still growing, as shown by a comparison of the figures of the 1930 census with those of previous censuses, are located definitely along the chief thoroughfares of the country, both rail and road.

DISCUSSION OF SPECIAL AREAS

New England

In a special study of the population of New England [7] decline was found to have started in southwestern New Hampshire and south-

[7] Dodge, as cited in note 3.

eastern Vermont as early as 1790, and to have progressed northward, the northernmost townships in the two states reaching peaks in the period 1880–1920. Although the full significance of this decline has not been worked out, some of it appears to be the result of the practical exhaustion of timber resources in the northern part of New Hampshire and Vermont.

Michigan

The decline of population in the northern part of the Southern Peninsula of Michigan [8] (Map 17) shows that the incidence of decline comes with the census dates 1900, 1910, and 1920. The boundary between the area which started declining in 1900 and that in which the peak of population did not occur till 1920 is approximately the main moraine of the Port Huron morainic system.[9] East and north of the moraine the natural vegetation was largely coniferous, and west of it largely deciduous. The agricultural settlements which came after the peaks of the lumbering population were irregular in their growth and decline, partly because of the "land-booming" character of the advertising that was a prelude to the installation of a farming population in the cutover areas. The settlements were sustained longer in the coniferous area than they were to the west, in the deciduous area, a condition for which there seems to be little logic, except for the manufacturing of the Alpena district. The only towns in the northern part of the Southern Peninsula of Michigan which have not suffered some decline are Ossineke in Alpena County, Rogers in Presque Isle County, and Gaylord in Otsego County.[10]

The Corn Belt

Practically the entire Corn Belt has been undergoing depopulation since 1900. In a few places, however, the depopulation began earlier. The principal exceptions to this general rule are found in the counties near the larger cities, such as Chicago, Columbus, Cincinnati, Indianapolis, St. Louis, and Peoria. Elsewhere, locally, counties have been able to maintain their population in a growing state. A sig-

[8] Dodge, as cited in note 4.

[9] Leverett, Frank, and Taylor, Frank B., *The Pleistocene of Indiana and Michigan* (Washington, Government Printing Office, 1915), pp. 294-300; Davis, C. M., "The High Plains of Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 21 (1935), 303–342. 1936.

[10] Dodge, as cited in note 4.

nificant study recently published by Thornthwaite [11] gives a general picture of the migration which has brought about the condition of population indicated.

Missouri

The depopulation which has affected the Corn Belt has spread over the greater part of the State of Missouri, not only within that northern part which may be considered a portion of the Corn Belt, but also to the south in the Ozark Highland. Practically the entire state, with the exception of St. Louis, has suffered. Decline in Missouri was first revealed in 1890, in a belt of counties from west of Hannibal on the Mississippi on the northeast to Bates County along the western border in the southwest, through Cooper and Saline counties on the Missouri River. For the most part, this was an area with a high percentage of land in farms in 1910, and the improved acreage was large, running, in general, from 80 to 100 per cent, in contrast with the Ozark area itself, in which the improved land was on an average nearer 50 per cent of the total.[12] The contrast in stability of population between the northern and the southern parts of Missouri suggests that the reason for depopulation of the Corn Belt may be looked for in the difference in the standards of living of the people of the two areas. The people with relatively high standards have not been able to use Corn Belt land of higher productivity and maintain or increase their population numbers so successfully as the people with lower standards who inhabit the Ozarks. Although this latter area has experienced some decline the percentage has not been so great.

Colorado, New Mexico, and Arizona

In a group of counties in central and southwestern Colorado and again in a belt running from northeastern New Mexico to southeastern Arizona marked depopulation has occurred. Furthermore, the peaks of population, as revealed by the decennial census, occurred as early as 1870. In Lake County, with the mining town of Leadville, and in Telfer County, containing Cripple Creek, the peaks are of the

[11] Thornthwaite, C. Warren, *Internal Migration in the United States* (Univ. of Pennsylvania Press, 1934), pp. 5–18.

[12] Sauer, Carl O., *The Geography of the Ozark Highland of Missouri* (Univ. of Chicago Press, 1920), pp. 180–182.

date 1900. Decline of more than 50 per cent in Lake and Telfer counties and of more than 25 per cent in Park, which lies between them, suggests the pronounced effect of the depopulation, supported by field observation showing vacant houses and stores in both Cripple Creek and Leadville. In Leadville the population reached 7,508 in 1910, but in 1930 was only 3,771, making a decline of 49.7 per cent in twenty years.

The area of decline in New Mexico is of more recent date, the peaks having been reached in 1910 and 1920, but the percentage of decline has been as much as in Colorado. Again, the abandonment of mining areas seems to be at least partly responsible for the altered demographic conditions.

Lower Mississippi

In the brief discussion which limited space makes necessary, a complete account of all the areas of population decline has not been possible. The Corn Belt, the western mining areas, and the New England and Michigan lumbering areas have been used to suggest some of the aspects of decline. Two more areas, one in the lower Mississippi Valley and one in Georgia, will be used to illustrate conditions in these portions of the United States, for they differ in social and economic conditions from those of the North.

Decline of population of more than 50 per cent stretches in a belt from Issaquena County, Mississippi, midway in the state along the Mississippi River, to the Delta. It is significant that the greater decline is on the east side of the river and not on the west. In northern Louisiana the population has been maintained at or near a peak for all the Mississippi lowland counties. Furthermore, the date of the population peak in the Mississippi area of decline is 1910. The cotton boll weevil reached this section in 1907–8. Throughout the greater part of the area, the yield of cotton had dropped from more than 250 pounds per acre in 1889 to less than 100 pounds in 1909.[13] The farms were operated generally by Negro rather than by white tenants or croppers in 1909, which suggests a racial rather than a physical or a biological geographical basis for the socioeconomic conditions which are the presumable causes of the decline.[14]

[13] Stine, O. C., and Baker, O. E., *Section A, Cotton*, in Baker, O. E., *Atlas of American Agriculture* (Washington, Government Printing Office, 1918), p. 15.

[14] *Ibid.*, pp. 12–13.

Georgia

The area chiefly affected by decline in Georgia is likewise one occupied largely by Negro tenants, which appears to confirm the hypothesis advanced at the end of the preceding paragraph as the principal "cause" of the decline, although it is not in these areas primarily that the trek of Negroes to northern cities originates.[15] This area in Georgia is, furthermore, one of a relatively large number of plantations having five or more tenants.[16]

The foregoing paragraphs merely outline some of the problems encountered in the study of population decline on a geographic basis. More detailed work will have to be done before any but the most tentative conclusions may be presented. In previous publications dealing with phases of the geographic problem indicated a county or a larger base has been used by most investigators. This, as pointed out earlier, may lead to an erroneous picture of the actual state of affairs. Refinement on a township basis, with ultimate detailed checking and elaboration by field methods, is needed before a really satisfactory geographical solution may be given. Even then, however, it is apparent that the whole problem is one of great complexity, involving as it does study of social, historical, and economic conditions, as well as investigation of geographical details, including the physical or geognostic base of the cultural geography.

REFINEMENT OF INVESTIGATION

In the last analysis, even the township basis of distribution becomes too broad, but beyond that it is impossible to go with the data published by the United States Census Bureau. The ultimate refinement, in areas of special interest, must be accomplished in the field and by other methods. In an article of great significance Goldthwaite has contributed an example of the results which may be derived from the use of earlier and later maps, supported by investigation in the field.[17] The abandonment of houses and roads in Lyme, New Hampshire, is worked out in this article with considerable skill, through a series of four maps: one was published in 1855; the second (1830, the date of maximum population) was deduced from the first on the basis

[15] Thornthwaite, *op. cit.*, Plate V. [16] Baker, *op. cit.*, p. 11.

[17] Goldthwaite, J. W., "A Town That Has Gone Down Hill," *Geog. Rev.*, 17: 527–552. 1927.

of field work; the third was published originally in 1892; and the fourth was the result of the field work in 1925. By this means the precise area of abandonment could be worked out, and the process of decline since 1830 could be shown. Unfortunately, but little, if any, of this refined investigation has been carried on in other areas, in spite of the great significance of the results which might be accomplished by its careful application in areas for which the requisite early maps are available.

In refined studies of this kind field work is essential, although the necessary interpolation may be done in a laboratory. Even without early maps showing the location of houses some progress in the detailed mapping of the areas of abandonment may be made by field plotting of abandoned sites (cellar holes) and houses, with a check against the United States Geological Survey topographic sheet of the area, if such exists.

Either by the more elaborate method evolved by Goldthwaite or by the simpler, but on the whole less satisfactory, method suggested above as a substitute when existing maps are inadequate, the true area of abandonment may be mapped. House abandonment, however, does not mean land abandonment. The abandonment of houses may be correlated with the decline of population, but the land vacated by one owner or tenant may be combined with other land and operated as part of a farm of larger size by someone remaining on the land, or it may be put to some other use requiring a smaller local population. This subsidiary problem is of a somewhat special kind, and requires, moreover, a different technique of investigation. The present paper deals only with the actual decline in the number of people.

CONCLUSION

Abandonment and land utilization

It is in the areas of recent more or less heavy population change that some of the more serious problems in land utilization have arisen. Detailed studies, such as those suggested above, carried on rigorously in the areas for which the indication of decreasing population has been made here on a county basis, should furnish an increasingly valuable body of data upon which to base rational conclusions and workable policies.

Abandonment and landscape change

Decade-by-decade geographical analyses of population change are, as suggested previously and elsewhere,[18] a sure method of arriving at the economic and historical material which must be integrated with the geographical for a fully rounded study to be developed. Geographically the coincidental landscape change is the most important thing, and this can be worked out best in the field by following, for the major part of the work, the method suggested by Goldthwaite, and, for the remainder, by determining the progress of vegetation succession toward a new climax, the extent of soil erosion, the coming back of species of wild animals previously exterminated in the area, and, in short, any geographical investigations which might be pertinent.

Throughout a large part of the United States the cartographical examination of the population data given by the successive censuses shows that rather large areas have been affected by population decline of lesser or greater magnitude. The areas thus blocked out were examined further for the dates of the culmination of population numbers, and this further examination revealed that in some cases it was possible to find, by the methods employed, a clue to the economic and social forms which were, in a way, causes of the changes. In addition, the foregoing study indicates that the county basis provides too coarse a mesh for accurate study, especially in those areas where the counties are large, and that the township base would give a more accurate foundation for study, though ultimate refinement could be accomplished only in the field.

The regions outlined, in New England, Michigan, the Corn Belt, Missouri, Colorado, Arizona and New Mexico, and Georgia and Mississippi, are but a few of the significant areas that Map 17 depicts. All merit further study on a more adequate, because finer, base if a thorough understanding of the whole complex of causes and results, both demographic and geographic, is to be had.

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[18] Dodge, as cited in note 3.

A QUANTITATIVE COMPARISON OF METHODS OF MEASURING LAND USE

PRESTON E. JAMES

RECONNAISSANCE in geographic field studies are investigations gradually emerging from a period of hit-or-miss observation to one in which some kind of measurement is demanded. Various techniques have been suggested from time to time by which reconnaissance observation may be governed systematically, and from which quantitative results may be obtained. One which has been given wide application was suggested by Professor Charles C. Colby.[1]

Colby's technique consists of the measurement of the frontages of the various forms of land use along a line of travel. From data gathered en route the proportion of the total line occupied by each form of land use can be computed and the results used as a rough indication of the proportional *area* occupied by each. To what extent, however, the linear measurement can be used to give such a rough indication needs further study. An areal survey, by W. J. Berry,[2] of the district through which Colby's railroad traverse passes indicates that the proportions worked out from the areal mapping were not significantly different from those derived from the linear measurements. Two questions, however, might be raised: What is a significant difference? and Would similarly satisfactory results be expected from the measurement of all farming communities?

The answer to the first question can scarcely be given at this time. It must await a much greater body of data, and also a continued clarification of objectives. To the second question, however, some tentative answers may be suggested. In general, the extent to which a linear survey can be depended on to reveal the essential characteristics of an area depends on the way in which the line cuts across all the various features which are distributed within the area. Where

[1] Colby, C. C., "The Railway Traverse as an Aid in Reconnaissance," *Annals Assoc. Am. Geog.*, 23: 157–164. 1933.

[2] Unpublished manuscript, Department of Geography, University of Chicago.

these features are arranged in more or less parallel belts the linear survey at right angles to the belt pattern can be used to give a thoroughly representative picture. But where the features to be measured are themselves arranged with reference to the line — some attached to it, some remote from it — then the linear survey gives a quite inadequate picture.

The extent, then, to which the linear survey can give satisfactory results depends on the character of the settlement pattern. Where the land-use features are distributed with reference to the main road, that road cannot be used for a representative traverse without "significant" errors. Where the main road cuts independently across the local settlement pattern, as some modern trunk-line automobile highways do, then such a road may well be used for the traverse. In most American communities the railroad is quite independent of the local patterns and so may give satisfactory results when used for the linear survey. But there are certain pioneer communities, established after rather than before the railroad, where the settlement patterns are distinctly articulated to the main line of travel and where the roads are essentially secondary. The railroad traverse of such areas should be less dependable.

An area in southern Kentucky on the Highland Rim offers a chance to compare a road traverse with an areal measurement of the same district. The land use of an area about twelve miles long by three miles wide was mapped by students at the University of Michigan Field Station.[3] The highway, which forms the axis of settlement in this area, is roughly twenty miles in length. The linear frontage of the various forms of land use along this road was measured, and the proportion of the total line occupied by each element was computed (Table I). With the aid of a planimeter the areas occupied by these use types were measured, and the proportions of the total area similarly computed. The area in question was limited to the so-called karst upland, so that no measurement from the very different landscapes of the neighboring Cumberland Plateau appear in the results. A comparison of the two forms of measurement is presented in Table I.

It seems that there are certain significant differences between the

[3] For a sample of this area see Map 8 in an article by Henry Madison Kendall, "The Highland Rim in the Vicinity of Mill Springs, Kentucky," *Pap. Mich. Acad. Sci., Arts and Letters*, 12 (1929) : 228. 1930.

TABLE I

LAND USE IN THE MONTICELLO AREA

Forms of land use	Percentage		Percentage of difference
	Total road frontage	Total area	
Farmsteads and villages	24.5	4.2	+ 483.3
Cropland			
Corn	18.6	25.0	− 25.6
Wheat	4.1	4.6	− 10.9
Other grains	3.3	4.0	− 17.5
Tobacco	6.3	2.6	+ 142.3
Hay	14.1	8.5	+ 65.9
Garden	1.4	1.6	− 12.5
Melons	0.7	0.3	+ 133.3
Miscellaneous	1.2	1.0	+ 20.0
Pasture			
Permanent, cleared	10.6	20.5	− 48.3
In rotation	7.1	8.5	− 16.5
Woodland and brushland	2.7	9.7	− 72.2
Ungrazed woodland	3.3	5.9	− 44.1
Wasteland	1.4	2.0	− 30.0

results of these two methods of measurement. Farmsteads and villages in this settlement pattern are closely attached to the main highway, and the proportion of the linear measurement which they occupy gives an entirely fictitious idea of the settlement density in the area as a whole. Considering the probable errors of mapping and measurement, it does not seem that significant differences are to be discerned in the proportions of the different kinds of crops. Possibly an explanation of the concentration of tobacco and melons along the road should be sought. The linear measure gives much too small a proportion to those forms of land use which are generally remote from the road, such as the various forms of permanent pasture, and the woodlands and brushlands either grazed or ungrazed.

With the aid of more comparisons of this sort perhaps some formula could be worked out by which a correction, applied to linear measurements, could be used to bring the results more closely into harmony with the areal measurements.

UNIVERSITY OF MICHIGAN

THE KANKAKEE "MARSH" OF NORTHERN INDIANA AND ILLINOIS

ALFRED H. MEYER

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INTRODUCTION

SYSTEMATIC studies in land utilization, such as have been undertaken in recent years by the Federal Departments of Agriculture and of the Interior, by the Michigan Land Economic Survey, and other state departments, together with the researches conducted by various public and private agencies as reported in the bulletins of the New York Social Science Research Council, all reflect the need for a scientific analysis of the land-utilization problems of the United States.

Regions which at one time or another have experienced competing and conflicting claims to land use generally furnish excellent material for land-utilization studies. The Kankakee marsh reclaimed area of northern Indiana and Illinois is such an area. Here clashed the interests of the hunter-sportsman-conservationist group with those of the organized land companies and of individuals interested in the reclamation of the wet lands for agricultural use. The author's interest in the region was aroused several years ago as a result of public propaganda and a petition to the Federal Government by a group of the Izaak Walton League to restore at least a part of the original marsh-swamp, once nationally famous for its wild life, particularly wild fowl. Studies of this type especially recommend themselves today in connection with the nation's agricultural and conservational readjustment policies.

The Kankakee country represents essentially an intermorainal marsh reclaimed valley extending from South Bend, Indiana, southwestward to Momence, Illinois. Down the wide, flat-floored valley coursed the original meandering Kankakee River, now a series of straight ditches. Rising in the east within a few miles of the St. Joseph River, tributary to Lake Michigan, and itself forming a headwater branch of the Illinois River to the west, the Kankakee, with

the St. Joseph portage, provided a strategic connecting link in the Great Lakes–Mississippi route of the early French explorers, fur traders, and missionaries.

Serving successively in its native state the Pottawatomie hunter, the pioneer trapper, the marsh-hay ranger, and the professional sportsman, the modern Kankakee, dredged, ditched, and drained, has added over a half-million acres to the famous drift farming section of the Central Plains.

The Kankakee is located in the more favorable humid section east of the Mississippi. Its summer isothermal position places it within the "a" subdivision of the Df climatic type of the Köppen system, and fairly well within the northern border of the Corn Belt (Map 19).

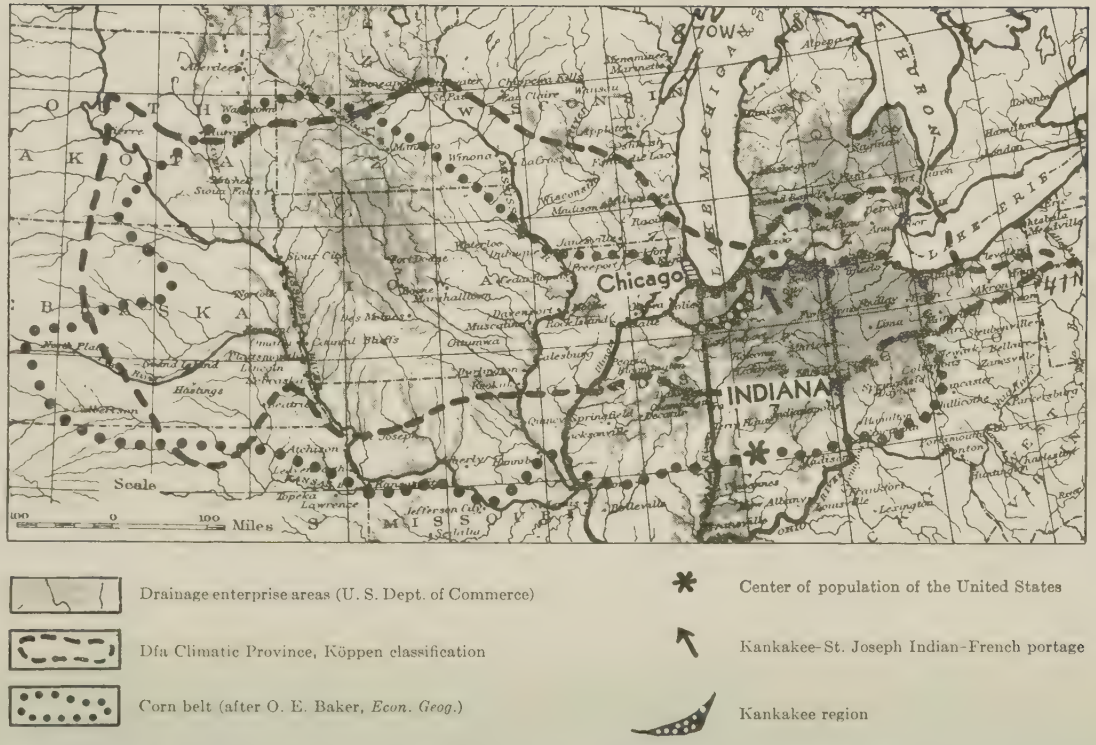
Demographical relations are no less significant. Rimmed by a score of towns, the marsh at the eastern end is terminated by the industrial city of South Bend, while its western extremity is within 45 miles from the second metropolis of the country — Chicago (Map 20). Less than 150 miles from the center of population of the United States, its valley is "within 3–24 hours by express or 5–36 hours by freight of at least half the population of the United States" (1, p. 34).

THE FUNDAMENT — THE "NATURAL" KANKAKEE

Marsh prairies of aquatic sedges and grasses, potential grazing areas; wild-rice sloughs, scenes of countless wild geese and ducks; flag ponds, lined with muskrat houses; a narrow but almost uninterrupted swamp forest, full of game, rimming a meandering river teeming with fish; the wet prairies, made humanly habitable by the interspersion of sandy island oak barrens surmounting the highest flood waters — such in brief is the physical setup which attracted the squatter pioneer from the East, who sought contentment in the solitude and seclusion of a marsh wilderness.

In the eyes of the reclamationist a half century later this same general scene reinterprets itself as an open prairie, practically unencumbered by a forest cover, with a flat valley floor, a high water table, and a presumably rich alluvial river bottom soil, located within 50–100 miles of the greatest stock and grain market in the world.

The cultural subtractions and additions incident to the drainage operations have modified almost beyond recognition the general areal picture of the prereclamation period. Yet certain elements of


Chicago
INDIANA
Scale
100 0 100 Miles
Drainage enterprise areas (U. S. Dept. of Commerce)
Dfa Climatic Province, Köppen classification
Corn belt (after O. E. Baker, Econ. Geog.)
Center of population of the United States
Kankakee-St. Joseph Indian-French portage
Kankakee region

MAP 19. Areal location and classification of the Kankakee (base map after *Census of the United States*, No. 15, U. S. Dept. of Commerce, Bureau of the Census, 1930)

CHICAGO
LAKE
MICHIGAN
LAKE CO.
PORTER CO.
LAPORTE CO.
ST. JOSEPH CO.
STARKE CO.
MARSHALL CO.
JASPER CO.
NEWTON CO.
ILLINOIS
INDIANA
KANKAKEE RIVER DITCH
REGIONAL RELATIONS OF THE KANKAKEE
APPROXIMATE BOUNDARY OF ORIGINAL MARSH PROPER EMBRACING AREA OF PRESENT GEOGRAPHIC STUDY
Author's strip usually extends two or three miles beyond line
MORAINE INCLUDING SOME GROUND MORAINE AND ASSOCIATED DRIFT PARTLY MORAINIC OR NOT DEFINITELY MORAINIC
SANDY-GRAVELLY PLAINS AND CHANNELS OF GLACIAL DRAINAGE, ALSO SANDY LAKE DEPOSITS
Glacial phenomena, after Leverett, Monograph 53, U. S. G. S.
STRAIGHTENED RIVER COURSE
RAILROAD
After State Department of Conservation, Indiana
DRAINAGE DITCH
Base map, after U. S. Engineers' Office, Chicago, 1915

Map 20

the natural landscape and their influences on human culture persist in general outlines to this very day. Many of the marsh dunal islands, particularly the unoccupied ones, and much of the original "meander lands" along the Kankakee River are still marked as of old by timber growth of upland and swamp species respectively.

The "islands" presently encompassed by dry land continue to be the preferred sites of regional settlement.

GEOMORPHOLOGY

The conditions of the surrounding terrain in relation to the agricultural economy are as significant as the "islands" in respect to the human habitat. The latter, rising conspicuously in the form of sand dunes, were recognized at the outset as "barrens" and as generally unsuited to cultivation. But the soil conditions of the flattish marsh areas appear, for the most part, to have been known only superficially and classified categorically with the common types of river bottom and marsh lands. Whatever typical surficial lowland charac-

teristics they may otherwise exhibit, the subsoil and "islands" of the Kankakee are structurally unique. Sand, with local lenses of gravel or clay, constitutes the basic structural material of the valley, while mounds and ridges of typical wind-blown sand here and there commonly attain heights of from ten to fifteen feet, surmounting the seas of water-laid sand.

Reference to their hypothetical origin may help one to understand the situation. Occupying an intermorainal position, with the Valparaiso moraine on the north and the Maxinkuckee moraine on the east and southeast, these clastic deposits have been classed by Chamberlin (11, pp. 330-331) and Leverett (18, p. 338) as mostly outwash.[1] Part of the valley fill has been attributed to the postulated Kankakee outlet for the glacial waters escaping from the Saginaw lobe by way of the St. Joseph channel at South Bend (18, p. 338; 20; 21, pp. 12-14). Bradley attaches great depositional significance to the former lake waters occupying the basin which he denominates the "Old Lake Kankakee" (6, pp. 226-229). Since many of the sand mounds and ridges are elevated above the highest possible level of the postulated lake or of the actually known marsh waters, which must have been shallow in either case, the sand of the higher elevated spots are clearly aeolian in origin, as is attested by their form and characteristic dune structure.

HYDROGRAPHY

For some eight or nine months of the year water from one to four feet in depth covered an area from three to five miles wide on each side of the river (1; 12). The area thus assumed the characteristics of a lacustral river rather than of an ordinary marsh. Especially was this true at the time of the winter ice jams and spring freshets. Having an elevation of approximately 720 feet at its source at South Bend, the Kankakee River trailed its way tortuously along the very slightly sloping and much oversized valley to a point near Momence. Here, at an elevation of 615 feet, it encountered a natural dam of Silurian limestone outcropping in the river bed. Within the small drop, then, of a little over 100 feet the river, totaling a meandering distance of some 250 miles, averaged a gradient of only about 5 inches per

[1] Though acknowledging the apparent "glacial" character of the continental "drift" deposits, the writer of this paper does not subscribe to all the implications of "Pleistocene glaciology."

FUNDAMENT OF THE KANKAKEE MARSH of NORTHERN INDIANA – ILLINOIS

LANDFORMS DRAINAGE NATURAL COVER

Based on original Federal township surveys of a century ago

By ALFRED H. MEYER, Valparaiso University
January, 1934

LEGEND

UPLANDS — Dominantly elevated and dry, more or less sandy areas, representing "barrens" or covered by an oak timber association

MARSH — Dominantly low and wet areas with a marsh herb formation, including locally swamp outliers

SWAMP — Main stand of thick swamp timber, mostly flooded

INDIAN MOUNDS

EXPLANATION

Like the historian who reviews the sequence of previous events to help explain present-day phenomena, the geographer may to advantage examine antecedent conditions of a landscape, particularly those dealing with the "fundament," the physical set-up prior to its modification by man. Such a retrospective geographic analysis not only reveals man's environmental heritage, but is of vital importance in land-utilization studies, particularly in such areas as the marsh reclaimed Kankakee, where there has been agitation to restore some of the marsh as a haven of wild life and a retreat of the recreationist.

This map and notations reveal the plant-restoration potentialities in the way of food and shelter for various types of game. The companion map, the chorographic map, supplies data on culture incident to the reclamation program in addition to the existing natural forms of the environment, all of which are significantly involved in any program contemplating partial marsh restoration or other changes in land utilization.

This map represents a composite adaptation of 28 separate township plats (12 inches square) and an additional number of fractional units. It is to be noted that the original Federal survey by townships consisted of several assignments, that observations as a rule were recorded only along section lines, and that the survey was doubtless influenced by changing seasonal conditions. Problems too are involved in interpreting or "interpolating" some of the plat data to make composition of the larger map possible. From the standpoint, then, both of the original survey and of the form in which it is here presented, the fundament map is intended merely as a generalization of natural landscape conditions.

THE "NATURAL" KANKAKEE

Marsh prairies of aquatic sedges and grasses, grazing areas; wild rice sloughs, scenes of countless wild geese and ducks; flag ponds, lined with muskrat houses; a narrow but almost uninterrupted swamp forest, full of game, rimming a meandering river teeming with fish; wet prairies made humanly habitable by the interspersion of sandy island oak barrens, many of them surmounting the highest flood waters—such was the general physical set-up of the "natural" Kankakee.

HYDROGRAPHY

With water covering the sand-filled, flat-floored valley basin, from 3 to 5 miles on each side of the river, 1 to 4 feet deep, for eight to nine months of the year, the area assumed the characteristics of a lacustral river rather than those of an ordinary marsh. The river rising at an elevation of 720 feet near South Bend dropped only about 100 feet in its meandering course of 250 miles down to Momence, where it encountered an anticlinal ledge of limestone.

The low gradient of the stream, the much-oversized valley, the loose, easily eroded clastic sediments of the basin and river bed, the swamp vegetation, and the frequently occurring floods conspired together to make of the Kankakee a notoriously rambling and snag-infested stream, ever abandoning old and establishing new channels, producing an intricate maze of meanders, oxbow lakes, sloughs, and bayous.

What appears to be the earliest description of the upper reaches of the Kankakee River is that of Father Hennepin (1683), translated by Shea (1880): "The river Siegnelay [French designation of the undifferentiated upper Kankakee-Illinois] is navigable for canoes to within a hundred paces of its source and it increases to such an extent in a short time that it is almost as broad and deeper than the Marne. It takes its course through vast marshes, where it winds about so, though its current is pretty strong, that after sailing on it for a whole day we sometimes found that we had not advanced more than 2 leagues (about 6 miles) in a straight line. As far as the eye could reach nothing was to be seen but marshes full of flags and alders."

The Federal surveyors' township plats suggest that the marsh, like the swamp river, presented a complex pattern—a maze of multiple marshes interspersed with sinuous sandy ridges, mostly designated as "oak barrens."

Though the larger tributaries in the east succeeded for the most part in establishing normal confluences with the master stream, those of the middle and lower stretches practically lost their identity after descending from the marginal moraine, debouching as they entered the stagnant marsh waters, where they formed delta-like deposits, and distributaries (T. 33 N., R. 5 W.). The Yellow River, most important tributary of the upper Kankakee, united with it where it expanded to form what is known as English Lake.

NATURAL VEGETATION

The map and extracts from the surveyors' records, together with inferences drawn from the present character and distribution of the natural cover as shown by the inventory map, reveal the nature of the original vegetation. Roughly, three formations may be recognized: the river swamp timber, the marsh sedge and grass including occasional outliers of the swamp timber, and the upland "barrens" or oak timber association.

THE SWAMP

The swamp timber proper follows the course of the river from practically the western extremity of the basin halfway up to its source, averaging perhaps a width of scarcely a mile, but widening considerably in its middle course, where it attains the maximum of nearly three miles. The stand included trees of extraordinary size, 2 to 3 and even 4 feet in diameter, once an important source of lumber for northern Indiana, while acorns of pin oaks and of a variety of other oaks supplemented the marsh wild rice diet of wild geese and ducks. Uriah Briggs, one of the Federal surveyors, thus describes the swamp: "The Kankakee River is a sluggish stream, its banks very low and lined on each side with a heavy growth of timber, mostly ash, some elm, maple, oak, and birch, which grow very tall, and is undergrown with swamp alder and wild rose, etc., making an interminable forest."

As late as 1911–12, and only five years before the straightening out of the lower reaches of the Indiana Kankakee, the State Commissioner of Fish and Game gave the following account: "The river courses through a forest of great elms, and trees such as grow on wet ground, and the branches of these hang near, or touch the water. Some of the trees are beautifully hung with vines, and all in all the scenery is altogether unlike that of any other river in Indiana. . . . Beautiful birds flush at every turn, kingfishers, green herons, great blue herons, wood ducks, mallards, hawks, owls, occasionally a great eagle, many red heads, flickers, red wings, divers, mudhens—all these and others are there in plenty. . . . Fish disturb the water. Set your hooks for them. Some of them are carp, but not all; many are catfish up to 15 pounds, walleyed pike of like weight, ordinary pike, or pickerel of weight sometimes nearly twice as great, and bass, large and small mouthed, up to 5–6 pounds."

Logging along the Kankakee as seen from Baum's Bridge before the straightening of the lower part of the river. (Courtesy of J. H. Durand of Valparaiso, Indiana.)

It is the wide river swamp unit referred to above, included in northern Jasper, southwest Porter, and southeast Lake counties which holds out today the greatest promise to the swamp-restoration enthusiast. Representing a tract of some 10–12 sections, essentially unoccupied and unutilized, its extensiveness and wildness are somewhat reminiscent of pre-reclamation days. But the primeval wilderness of virgin timber, with its profusion of animal life, has all but disappeared, leaving only a semblance of its former glory in those tracts which, though exploited for their merchantable timber and firewood, have been spared the ravages of fire and disease. Extensive areas affected by the latter form of clearing present the most pitiable spectacle of despoliation —a veritable "No-Man's Land."

THE MARSH

Rank sedges and grasses, fields of wild hay and wild rice, dominated the marsh landscape interrupted now by the swamp timber outlier of pin oak and its tree associates, now by a pond or a lake of lily pads, reeds, cattails, and flags. The tall huckleberry and cranberry presumably were important seasonal contributors of food for man and bird. The small tamarack swamps marked on the map have disappeared; wild rice, once the harvest-haven of wild fowl, was found by the author in only one locality—in a drainage ditch; while marsh hay appears as a relict formation in small and widely scattered, poorly drained strips or spots, generally pastured, which the dredge and the plow have not yet invaded.

THE UPLANDS

The insular dunal and other uplands rising just above the shallow water or to conspicuous heights of as much as 25 to 35 feet, either supported only a thin herb or moss ground cover reflective of acid soil conditions, or bore a stand of scrub or medium-sized timber consisting chiefly of black oak and white oak, the latter now mostly extracted. As in the case of the wet marsh, the drier sandy uplands contributed their seasonal offerings: dwarf huckleberry, blueberry, blackberry, and dewberry, and hazel and other nuts. Many of these uplands are dunal in character and too sandy for agricultural uses other than furnishing a very poor grade of pasturage. Hence such areas, where large enough, and not too thickly farmsteaded, may be regarded locally as potential game propagation areas.

For the combined ridge and marsh setting let us consult the notes of another of the Federal surveyors, Mr. Smith, whose observations on T. 34 N., R. 1 W., are to the point: "The general appearance of the township is rather uninviting to the capitalist and the land speculator, but to the poor man and him who wishes to act the 'squatter' it holds out some inducements. The soil is generally sandy, and on the rolling parts loose and white with but little soil or vegetation. . . . In the wet prairies the sods are from 6 to 18 inches in height and about the same dimensions as to length and breadth. Their distances asunder, include every change of space from zero to 12 inches and of all the places ever a poor wight had to walk over with 'heads up' and 'eyes front,' they are the worst. The marshes or marsh prairies are smooth to walk over, but not a bit more pleasant to walk over than the prairies, for though we have not the stubby sods to be stumbling over continually we have water and a marshy substance to wade through and the whole placed upon a yielding elastic sod."

A detailed inventory of the associations of vegetation should aid the reader in reconstructing the early formations, while making the proper reservations, of course, for the changes that have taken place incident to reclamation.

1. MAPLE–ASH–ELM ASSOCIATION. — A swamp type occurring along the Kankakee and Yellow rivers within the belt mapped as Swamp soil. Silver maple, black ash and white ash, or water elm dominate practically every mixed stand. Accessory species include yellow birch and black birch, pin oak, white swamp oak, bur oak, popple, and sycamore. Reproduction timber of maple, or birch, or popple invasion, after a burn or a clearing, often forms nearly pure stands.

Shrubs and herbs include species of willow, alder, dogwood, spicewood, buttonbush, thistle, nettle, blackberry, horseweed, jewelweed, goldenrod, sedge, and grass. In unpastured areas, burns, or clearings, some of these, together with brush sprouts, often form rank jungle-like growths, difficult to penetrate.

2. PIN OAK–BLACK OAK ASSOCIATION.— A type of swamp outlier occurring as small patches within the prairie, transitional in situation and composition between those of the pure swamp and the true upland. Pin oak, a typical swamp species, is predominant. With it are mixed black oak and white oak, upland types.

Huckleberry, blackberry, chokecherry, and hazel are common shrub adjuncts.

3. WILLOW–MAPLE–COTTONWOOD ASSOCIATION. —A type identified with the larger drainage and river ditches and their associated spoil banks, often forming a sort of linear alignment, with willow banking the water's edge, the cottonwood surmounting the ridge together with silver maple and, less commonly, with other swamp species. The whole is frequently netted together by the grapevine on the river bank.

Sand sedges and grasses, Equisetum, milkweed, cinquefoil, and butterfly weed represent but a few of the large variety of xerophytic or other upland types of herbs occurring on the dry spoil banks and functioning in part as sand binders. In the drainage ditch below, the growth of aquatic sedges and grasses, species of bladderwort, algae, duckweed, water plantain, and cattail sometimes proves a troublesome current-retarding and ditch-filling factor.

4. BLACK OAK–WHITE OAK ASSOCIATION.— A type forming characteristically fixed dune groves so conspicuous in the otherwise flattish and naturally featureless landscape, or constituting the upland timber of the prairie margin. Either because of natural conditions or because of the removal of the white oak, black oak is nearly always the dominant and sometimes the exclusive species. Hickory is significant in only a few localities; occasionally red oak occurs. Pin oak characteristically forms a very narrow girdle at the base of the wooded knoll or sand ridge.

Dwarf huckleberry, blueberry, and blackberry are shrub associates of this timber type.

5. MARSH SEDGE–GRASS ASSOCIATION.— This type, once predominant over entire sections, today represents hardly more than a mere relict formation. A few local poorly drained pockets or ill-defined stream courses are characteristic sites. It is shown on the map by the conventional marsh symbol.

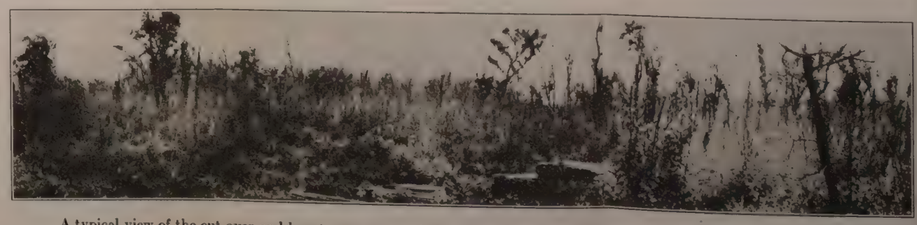
MARKS OF PRIMITIVE AND PIONEER CULTURE

Human occupance of the region and its outside territorial connections at the time of the Indian treaty and Federal survey are expressed in a way very definitely related to the terrain conditions. Three main trails or roads crossed the marsh. Two of the routes, the central and the eastern, followed the sinuous trend of the ridges and crossed the river where these natural "right-of-ways" most nearly approached it; the one skirting the marsh on the western extremity near the site of Momence crossed the river where an anticlinal limestone ledge makes an ideal fording place.

The main arteries of earliest travel established by the Pottawatomie and the pioneer thus become the historic highways which linked the Indiana points south with the Chicago and Calumet territory to the north, making connections thence with the route which extended from Chicago eastward to Detroit. Secondary Indian trails, as noted on the map, connected at various points with the main routes of travel.

It appears that both the redskin and the paleface originally practiced "transhumance" in the Kankakee region, occupying the marginal moraine uplands in summer and migrating into the swamp for winter hunting and trapping. Proximity to the river seemingly furnished the general situation of settlement, while the island ridges or oak knolls furnished the site. Evidence of Indian encampments is noted near the state line, also in four other townships on the map.

The more permanent white man's occupance forms shown on the map are community mills situated on the margin of the marsh, one on the main river at the west end of the marsh, several others on creeks tributary to the Kankakee (T. 36 N., R. 1 W.; T. 36 N., R. 2 W.). In the same townships the survey records in a few places rectangular outlines, presumably representing fields of grain or pasture.



A typical view of the cut-over and burnt-over swamp timber along the modern Kankakee. For the characteristic swamp composition see the description under "Maple–Ash–Elm association"

mile. The average gradient for the valley, 85 miles long, is about 15 inches (1).

The low gradient, the wide valley, the loose, easily eroded clastic sediments of the river bed, the swamp vegetation, and the frequently occurring floods thus together conspired to make of the Kankakee a notoriously rambling stream, ever abandoning old and establishing new channels. As a result, there was formed an intricate maze of meanders, oxbow lakes, sloughs, and bayous, similar to that depicted on the map by Ahlgrim (Map 22). Accordingly, the river did not prove a very satisfactory political boundary between the northern and the southern tiers of counties.

A glance at the Fundament map (Map 21) suggests that the marsh was not a single simple unit, but, like the swamp river, a complex affair — a maze of multiple marshes interspersed with sinuous sandy ridges of higher and drier land. Streams descending from the marginal moraine debouched into the stagnant marsh waters and formed delta-like distributaries and deposits (T. 33 N., R. 5 W.).

NATIVE VEGETATION

Roughly, three formations of the original native cover may be recognized: (1) the river swamp timber; (2) the marsh sedge and grass, including occasional small outliers of the swamp timber; and (3) the upland "barrens" or oak-timber association.

The Swamp

The swamp timber proper followed the course of the river from practically the western extremity of the "basin" halfway up to its source, averaging a width of perhaps scarcely a mile, but widening considerably in its middle course, where it attained the maximum of nearly three miles. The stand included trees of extraordinary size, two to three and even four feet in diameter, once an important source of lumber for northern Indiana. Ash, elm, maple, oak, and birch were the dominant species.

The Marsh

Rank sedges and grasses, fields of wild hay and wild rice dominated the marsh landscape, interrupted now by a swamp-timber outlier of pin oak and its tree associates, now by a pond or a lake of

lily pads, reeds, cattails, and flags. The tall huckleberry and cranberry presumably were important seasonal contributors of food for man and bird. The occasional small tamarack swamp has disappeared; wild rice, once the harvest haven of wild fowl, was observed by the author in only two localities — in drainage ditches; marsh hay appears as a relict formation in small, widely scattered, poorly drained strips or spots, generally pastured, which the dredge and the plow have not as yet invaded.

The Uplands

The insular dunal and other upland areas, rising just above the shallow water or to conspicuous heights of as much as 25–35 feet, either supported only a thin herb or moss ground cover reflective of acid soil conditions or bore a stand of scrub or medium-sized timber consisting chiefly of black oak and white oak, the latter now mostly gone. As in the case of the wet marsh, the drier sandy uplands contributed in superabundance their seasonal offering for man and beast: dwarf huckleberry, blueberry, blackberry, and dewberry and hazel and other nuts.

SEQUENT OCCUPANCE FORMS AND FUNCTIONS

The transformation of the Kankakee "haven of wild life" into a "modern home for man" may be treated under four stages of settlement: (1) the period of the Indian hunter and the French trader; (2) the immigration of the pioneer trapper and the frontier farmer; (3) the epoch of the stock farmer and the sportsman fowler; and, finally, (4) the present joint occupance by the Corn Belt farmer and the river resorter. These stages have been graphically synthesized in the Silhouette Study (Fig. 20).

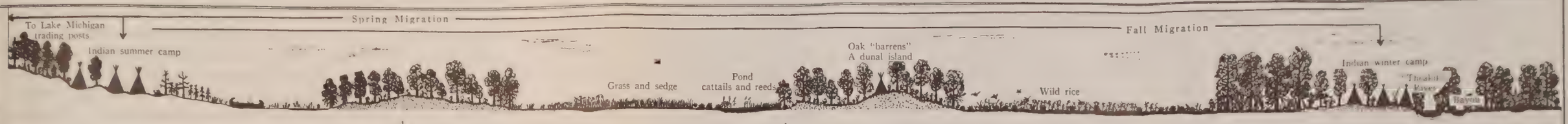
The first two stages are characterized essentially by human adjustment *to* the environment. The last one dominantly exhibits human adjustment *of* the environment. The third is characteristically expressive of a transitional condition in which the hitherto dictating influences of the marsh-swamp fundament became progressively weaker as the drainage net was perfected, leaving only remnants of the naturally induced culture forms reminiscent of an older and much more romantic period.

A SILHOUETTE STUDY IN SEQUENT OCCUPANCE OF THE KANKAKEE MARSH RECLAIMED AREA OF NORTHERN INDIANA AND ILLINOIS

By Alfred H. Meyer, Valparaiso University, January, 1934

NOTE—The present skyline sketches are intended to portray a regional synthesis of the Kankakee landscape by epochs. The profile represents a generalized view of one half of the width of the valley; comparative scale of phenomena not intended.

Essentially HUMAN ADJUSTMENTS TO THE ENVIRONMENT



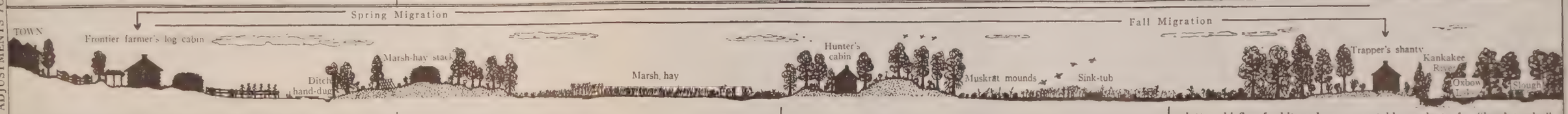
THE POTTAWATOMIE'S KANKAKEE (–1840) generally represents a wild morass of aquatic vegetation, a haven of wild life, a seasonal habitat and hunting quarters for the northwestern Indiana Indian.

Though some Indians occupied the marsh the year round, a certain number in summer would contact the French at fur-trading posts on Lake Michigan or select as their summer habitat the more desirable moraine bordering the marsh. In the fall the aborigine migrated into the marsh or swamp and established his winter encampment on one of the numerous high and dry dunal knobs or ridges interspersed throughout the wet marshes or marking the elevated sites along the river-swamp margin. Black oak and white oak constituted the chief cover; pin oaks, conspicuous for their dead lower branches, invariably marked the boundary between "island" and marsh, a phenomenon still very noticeable. These oak-covered "islands" afforded shelter, fuel, and game, and served as a refuge against the ferocious Iroquois of the East.

The surrounding higher marshes of sedge and grass grazed the Indian ponies, which "kept fat and wallowed in nature's choicest luxuries." The lower and wetter marshes of wild rice attracted countless numbers of wild fowl; the flag-, cattail-, and reed-filled shallow ponds of the marsh and the forest-rimmed bayous of the river in the swamp marked the sites of widespread colonies of muskrats; the meandering lacustral "The-a-ki-ki" teemed with fish.

From the standpoint of interregional communication between points north and south the marsh, which trended generally east-west for a hundred miles across northwest Indiana, proved to be a real barrier except where it could be crossed by three naturally favored routes—one in the east (near Mud Lake), one in the center (site of the historic Baum's Bridge), and one skirting the western extremity (site of Momence) These routes, together with wigwam sites, are shown on the original century-old Federal surveyors' plats, reduced by the author to a single map unit.

"Land" travel definitely was oriented in accordance with the distribution of the elevated sand ridges, the trails utilizing these to the utmost extent as they wended their way riverward or crossed any part of the marshes or swamp. Conditions of internal circulation otherwise generally favored rather than hindered the primitive mode of travel of the redskin, who, during three fourths of the year or more, could push, if not paddle, his way by canoe, in practically any direction he chose to go. The river served as a more special artery of travel and trade, by which, as in the case of Lake Michigan, the Pottawatomie was brought into contact with the French explorer and trader of the 17th and 18th centuries, who portaged into the headwaters of the "Siegnelay" (the undifferentiated upper Kankakee-Illinois) at what is now South Bend. and by this route penetrated to the Land of the Setting Sun, the "Illini" Prairies, and the Father of Waters to the west. The Pottawatomie's period of occupance came to an end by treaties with the Federal government in 1832 and 1836, which transferred the tribe to a western reservation.



THE PIONEER'S KANKAKEE (1840–80) presents practically unchanged the condition of the environment of the preceding period. Not unlike the Indian they displaced, the Danes, Swedes, English, and Germans, who migrated hither from the East, adjusted themselves most closely to their surroundings. Theirs, too, was the simple economy of "fur, fowl, and fin," supplemented commonly by gardening and occasionally by subsistence farming. Wild huckleberries, blueberries, blackberries, and locally cranberries grew in profusion, and contributed their seasonal offerings for home use and the market. Like the Indian, the marsh frontiersman practiced a form of transhumance, his movements synchronizing with the seasonal migrations of geese and ducks.

Occupying a hastily constructed shanty or, less commonly, a more substantial log cabin, on one of the marsh or swamp "islands," the squatter passed the winter hunting and trapping the ubiquitous muskrat and other fur-bearing animals. "Claims" to trapping territory were of specified width and extended strip-fashion from the river back into the marsh on either side. In summer the trapper might find employment in one of the towns growing up on the edge of the marsh or be hired out as a "hand" to one of the settlers cultivating a small clearing on the margin of the marsh, or possibly on one of the "islands" near it.

Crop lands on the marsh margin or "islands" usually were devoted to a little corn, wheat, and oats. These were fenced to keep out livestock, which grazed at will on the upper wet prairies of rank grass and sedge. Cut by scythe or sickle, marsh hay was transferred from the wet places, usually by a specially constructed sled, and stacked on one of the "islands" for winter foraging.

Sink-tubs, dugouts, and pushboats, expressive of the hunter's economy, were marks of culture of the lower and wetter marshes and of the swamp.

Logs of black ash and white ash, water elm, silver maple, pin oak, and other swamp species denote lumbering operations in the swamp, while clearings on the oak knolls of the smaller upland oak timber signify the cutting of trees for firewood, fence posts, props, and ties, the latter chiefly of white oak, an exportable product of a "legal tender" reputation.

Travel by foot, horseback, or vehicle, as in the previous epoch, generally followed the line of least wetness, while cattle seemed instinctively to be able to pick out the more elevated though frequently submerged pathways.

By 1880, it is reported, most of the old-time hunters had left the marsh, and townships could vote out the free range. Nels Morris, the famous Chicago packer, and others became interested in the Kankakee grazing and potentially grain-producing lands, and sportsmen's clubs recognized in the Kankakee, "the hunter's paradise."

Transitional

THE RANCHER'S AND THE RECREATIONIST'S KANKAKEE (1880–1910) presents a double ensemble of landscape characteristics: a cattle economy on the higher, drier, and artificially drained lands side by side with public shooting and trapping grounds of wild fowl and other game on the ill-drained marshes and swamps. It expresses a conflict of two sets of forces contesting for the use of the land, that of the reclamationist in competition with that of the conservationist.

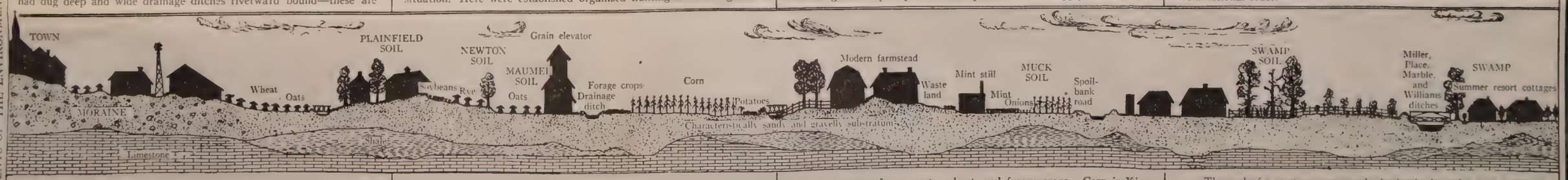
The axe encroaching on the swamp, the barbed-wire fence enclosing the mile-square ranges, the sickle mowing its swath in the wild-hay marsh, the plow breaking the prairie stubby sod where the steam dredge had dug deep and wide drainage ditches riverward bound—these are the animated aspects of a "country which God forgot to finish." Yet finished, indeed, from the naturalist's and the sportsman's viewpoint was this "Edenic playground" with its pristine vegetal and animal life providing scenery and sport reputed to be among the most alluring in the Central West.

In spite of the reclamationist's steam dredge, which made cultivable and habitable the surrounding prairies, the dunal island continued to hold its former power of attraction as a site of the human habitat, whether of farmer, fowler, or fisherman. Especially imposing were the double-story frame clubhouses, whose sites were a function of the river situation. Here were established organized hunting and fishing clubs from Chicago, Indianapolis, Louisville, Pittsburgh, and other large cities; also a number of resorts. Towns on the edge of the marsh and hotels along the river shared in the activities of the recreation industry.

Cultivation, formerly confined almost exclusively to the upland light sandier tracts, now came to be extended onto the lower reclaimed prairies, on loams subsequently classified as Maumee. The staples corn and oats complemented the natural resource of marsh hay in supporting a livestock industry, and, supplemented locally by wheat, forboded a grain culture on a cash-crop basis. Wild hay also furnished a cash income, from the exportation of bales for feeding, bedding, or packing, according to the quality. The swamp continued to supply lumber, and professional hunters engaged in shooting and trapping as a business and as a sport.

Ditch digging and road building went hand in hand, the spoil-bank gravel and the sand of the ditch often being utilized as roadbed material. Railroads, which transected the marsh in the previous period, now figured in the agricultural and the recreational development of the Kankakee, while small-craft river navigation assumed an importance never exceeded before or since. The straightening of the main river channel, begun in 1906, may be said practically to mark the culmination of this period, characteristically transitional from the old recreational to the new reclamational order.

HUMAN ADJUSTMENTS OF THE ENVIRONMENT Essentially



THE RECLAMATIONIST'S AND THE RESORTER'S KANKAKEE of the twentieth century (1910–) continues to express a dual occupance of the landscape, but by the straightening of the lower Indiana Kankakee in 1917 agriculture pushed the recreational interests clear out of the marsh and confined them to the river front, where they take the form of single or grouped cottage resorts.

The former wild hay of the upper marshes and the wild rice of the lower marshes or sloughs have given way to cultivated grasses and grains. Roads, drainage ditches, spoil banks, and fences demarcate 40-, 80-, and 160-acre rectangular field units, reflective of the far-flung flattish terrain and the ease with which it may be cultivated by the modern tractor. Irregularities of size and shape are now and then introduced by the oval or sinuous, oak-covered or pastured ridges, or by the drainage lines directed diagonally riverward.

The sandy "barrens" of the original surveyor become the "rolling Plainfield" of the modern soil classificationist. Composed of light, loose, thin, droughty soils, this dunelike formation is subject to "blowing" when the native cover is removed. Accordingly, many of these upland timber tracts show only local cutting for fence posts and firewood. Except on the heavier phases of this type, soybeans, cowpeas, rye, and certain truck products are practically the only crops grown. Although a characteristic woodlot-pasture formation, the Plainfield is noteworthy chiefly for its farmstead site quality. Considerable tracts represent true barrens, with only a cover of acid-tolerant plants, and therefore idle lands of no agricultural utility.

The Newton series, about one half as extensive as the Plainfield and together with it embracing about 20 per cent of the Kankakee, occupies a sort of intermediate position, physically and culturally, between the lighter, higher, and generally less fertile Plainfield, with which it is intimately associated, and the lower, heavier, and much more fertile Maumee.

The former wild-hay stock ranches and wild-rice duck-feeding grounds have by drainage been converted into the main crop lands of the Kankakee—the dark fertile Maumee and the organic Muck, which represent respectively some 60 and 15 per cent of the area. The productive Maumee dominates the landscape and includes the most extensive acreage of corn, oats, wheat, and forage crops. Corn is King in the Kankakee, whether on Maumee, Muck, or cleared Swamp lands, except locally, as in the East, where mint may assume a position of first importance on Muck areas.

The river Swamp, roughly the remaining 5 per cent, in the form in which it is found today on the Indiana side, represents an almost unmappable mixture of relict timber, of "burns," clearings, sprouting stumps, and reproduction stands. It has little merchantable timber or pasture value. Once reputed to be the most beautiful river in Indiana, the meandering Kankakee has been obliterated by the deep, wide, and highly banked ditches, known sectionally as the Miller, Place, Marble, and Williams ditches. Only remnants of the original winding channel, with its bayous, are still found.

The transformed river-ditch shows a most marked effect on resort developments. Only one half as many resort cottages occur along the lengthy straightened channel in Indiana, as along the few miles on the Illinois side, where the river has been left in essentially its natural condition.

The end of a century may mark the beginning of a new epoch of occupance, as Federal and State authorities, the Izaak Walton League, and others contemplate the feasibility of restoring a part of the swamp or marsh for game or recreational purposes. Such a program seemingly would modify present landscape conditions essentially only in the areas of marginal agricultural utility or waste lands, such as parts of the Swamp and certain unoccupied and unutilized tracts of the rolling and sandy Plainfield.

The general pattern, then, of agricultural settlement would likely change but little. Averaging nearly three per section, farmhouses are very unequally distributed. According to the author's field survey, their distribution on the Plainfield, Newton, Maumee, Muck, and Swamp areas approximates the following ratios: 22:1; 9:1; 5:1; 1.5:1; 1:1, respectively.

A sectional grid road system, 55 per cent hard-surfaced, makes for ready internal circulation and external contact with the rim of a score of towns which outline the boundary of the early marsh. Of these, South Bend is the ranking industrial and commercial city.

FIGURE 20

THE POTTAWATOMIE'S KANKAKEE
(—1840)

The French explorers, Charlevoix, La Salle, Tonti, and Father Hennepin, were the first to give an account of the characteristics of the Kankakee region. This valley they entered at its source near South Bend, Indiana, after experiencing much difficulty in locating the portage between the St. Joseph River, up which they had ascended from Lake Michigan, and the source of the Kankakee, which they regarded as the headwaters of the Illinois River. Here they came into contact with the Pottawatomie Indian, who found the marsh a refuge against the ferocious Iroquois of the East.

While some of the Indians appear to have settled more or less permanently on the marsh margin or on islands within the marsh or swamp, the majority seem to have migrated back and forth, in summer occupying the marginal moraine or Lake Michigan plain, and in winter retiring to the swamp (or marsh) island, as illustrated and described in the Silhouette Study (Fig. 20).[2]

At least six river, or near-river, island encampments are shown on the original Federal surveyors' plats.

Besides transportation, the river situation, like that of the Lake Michigan trading posts, favored communication with the French fur traders, who likewise came to use the swamp island sites as home and headquarters for carrying on their own trapping as well as for trafficking with the natives.

Encampments

Ball (3, pp. 66–67) reports a number of camps of Indians: "In the winter of 1835–36 about 600 had an encampment in the West Creek woodlands, where deer were abundant, and an encampment was there again the next winter." Another Indian camping ground was located south of the present Lowell. These would classify as marginal marsh

[2] J. Lorenzo Werich, a pioneer Kankakee hunter, whose mother settled with her parents within a few miles of the Kankakee in 1835 and whose father hunted in the marsh as early as 1852, writes to the author as follows:

"Indian Island near the Kankakee was the Indians' camping ground. During the hunting season of the fur-bearing animals, from early autumn to late in the spring, this island was their home.

"Along about the first of May they would pack their hides, furs, and with their squaws and children they would start for the Lake Michigan region to

situations, though the exact sites are not given. Among marsh island sites the author mentions Red Oak Island (Map 22), where in 1837–38 two hundred Indians had a garden and where there were two stores kept by French traders; also Big White Oak Island, south of Orchard Grove, where there was an Indian cemetery. Among the swamp island sites next to the river Werich (27) reports an "Indian Garden" at the mouth of Sandy Hook branch, tributary of the Kankakee (in Porter County), and another "Indian Island" a few miles farther down the river.

Trails and Roads

The trail routes, or pioneer roads, like the camp sites, clearly reflect the influence of the terrain. Again referring to the Fundament map we observe that three main lines of communication crossed the marsh. Two of the routes, the central and the eastern, followed the sinuous trend of the ridges, where they most nearly approached the river; the one skirting the marsh on the west took advantage of an anticlinal ledge of limestone in the river bed which made fording easy.

The route through the heart of the marsh crossed at the Pottawatomie Ford, which was destined to become the most historic spot along the Kankakee River in the marsh proper. Here was established in 1836 the Eaton Ferry, which transferred the early travelers across the one and one-half mile marsh between the Porter County sandy upland area and the sand-ridge landing in Jasper County on the side of the river opposite.

The epoch of Indian occupation may be said to close with 1840. By the treaties of 1832 and 1836 with the Federal Government the Pottawatomies relinquished their claims to the lands of northwest Indiana. A few were permitted to remain, those that had been especially friendly to the authorities, but these were absorbed in the pioneer trapper group of the next epoch, which we have dated from 1840 to 1880.

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meet the fur traders. . . . The Indians would stay along the lake front all summer, and early in the fall they would return to the camping grounds in the Kankakee swamps.

"About one mile up the river from Indian Island was another Indian camp ground, known as Indian Garden. The Indians in selecting a camp ground always located on a point of high land which was well fortified and could not be invaded by the enemy."

THE PIONEER'S KANKAKEE
(1840–80)

We are told that, after the initial marsh invasion by a sprinkling of French trappers and traders, the "upper basin of the Kankakee River was slowly taken over by the Danish and Swedish, and the lower by the English and some Germans" (16, p. 25). Ball (3), in speaking of the settlement of northwest Indiana, especially of the latitude of the Kankakee and north thereof, designates as the chief sources of immigration New England, New York, Pennsylvania, Ohio, Canada, the British Isles, Germany, Holland, and Scandinavian countries, with a few from south and central Indiana. Werich (27) refers specifically to the year 1833 as the time of the advent of the first white families from the East, the Morgans and the Dyes of Ohio, who settled in the neighborhood of Sandy Hook, referred to above. By the early 'fifties a number of pioneers had settled north of Knox, Starke County (14).

Though the immigrant farmer had a more or less fixed habitat, the pioneer squatter commonly practiced seasonal migration. He lived in a shanty on an island in the marsh or swamp during the winter trapping and hunting season and removed to the margin of the marsh in the summer, where he might "hire out" as a "farm hand" or find some kind of job in town.[3]

The island, though lonely, served its homesite function well. The sand base insured perfect drainage at all times; its vegetation, consisting of an upper story of oaks, a lower of scrub growth, and a ground cover of bush and herb, prevented the island from being blown away; the formation, a natural aquifer, provided a wholesome and abundant supply of water, naturally filtered; the timber furnished shelter and firewood; the ground cover often included dense growths of huckleberry and blueberry. As previously pointed out, this site had every advantage for exploiting game, fur, and subsistence food products.

[3] "The trapper built a shanty on a ridge or an island as the case might be and during the trapping season would live in his shanty. Along about April 10 or 15 he would take up his traps, store them in the shanty, pack up his furs, and move out of the swamp to his home wherever that might be. Along about October 1 the trapper would go back to his shanty. A few of the Kankakee trappers that had no other abode lived in their shanties during the summer season. Back in the 60's and 70's the border towns had many trappers." — J. L. Werich, communication.

Home of the Squatter Trapper

The typical trapper of the Kankakee occupied a shanty of one or two rooms most simply constructed of unfinished lumber and usually with a single entrance. It appears to have been a common practice for trappers to move about, remaining on one spot for only a few years, then going to another island, where a new shanty would be erected. Occasionally a more substantial structure would be built in the form of the familiar frontier log cabin.[4]

The distribution of such primitive shelters was of the most scattered type, a pattern definitely related to the dispersion of the island sites themselves. In the early days the population was exceedingly sparse; later on, when the trapping business assumed greater commercial importance, more trappers were attracted, until restrictive measures were adopted, including separate "trapping claims" laid out at right angles to the river (27, p. 87).

The revenue derived from game resources during this period can be only roughly estimated, on the basis of hunters' reports. Muskrats supplied by far the greatest bulk of fur marketed, but brought the low price of from 3 to 15 cents per pelt. However, what the pelts lacked in individual value was offset by their overwhelming numbers and ease of exploitation. It is reported that a trapper found muskrat houses so numerous that three or four could be speared from one position of the boat. Another trapper states that, after the great marsh fire in 1871 (incidentally the year of the great Chicago fire), he sometimes caught in a single night more than 80 "rats" in a line of 100 traps. In Lake County alone the annual catch during the period from 1834 to 1884 is said to have averaged between 20,000 and 40,000 (21, pp. 519–520).

Farm Economy of the Frontier

Farm economy, such as there was, and fur exploitation went hand in hand during the frontier occupance of the Kankakee. So closely were they associated that the form and function of the settlement of one were only a slight modification of the form and function of the other. The typical frontier farmer was also a hunter, and in

[4] The frontier "fur, fowl, and fin" environment and seasonal economy is well portrayed in a crude but detailed diary (1852) by a certain Josiah Granger (24).

no small measure supplemented his income and diet with the wild products of the marsh and swamp.

Though the ideal site of the trapper seems to have been a rather heavily wooded dune island in close proximity to marsh, swamp, and river, that of the farmer probably was the marsh margin, or marsh islands near the margin, and particularly those with a somewhat heavier soil.

Perhaps the outstanding fact of sequent occupance and utilization of farm lands in the Kankakee from the earlier days down to the present is the progressive expansion from the higher and drier, though generally much poorer, island and ridge soils to the lower and generally increasingly fertile soil types as they became available by drainage. This does not mean that the general agricultural development necessarily involved the abandonment, by the early settlers, of the original, and in some respects still preferred, sites of settlement. It is, rather, expressive of the areal spread of occupation as related to the growing drainage net and the early island sites, which represent the original nuclear farmstead attachments in the area. "There was the usual tendency to occupy first the lighter and the forested soils, because they were easier to handle with the primitive instruments employed than the heavier soils and prairie lands, and in addition the timbered areas furnished game, firewood, and building material" (8, p. 1701).

Wild grasses and sedges figured very significantly in the simple farm economy. They constituted the chief, if not the only, source of hay as well as pasturage. If the season favored the farmer, he might without much difficulty harvest the hay by a hand scythe or a mower. But should it be a wet summer, sleds, drawn by horses shod with sandal-like shoes, had to be used to haul the hay out of the marsh; or it was carried out on a pair of poles by two individuals walking tandem fashion. If it was impossible to reach the farmstead, the hay was temporarily stacked on an island near by and removed later to the farm premises when conditions permitted. Sometimes it had to be cut on the ice, which resulted in forage of rather inferior quality.

The farm routine of pioneer days was characteristically built up around the seasonal offerings of nature: in spring and fall, wildfowling; in summer, wild-haying, fishing, and huckleberrying; in fall and winter, trapping, hunting, and chopping wood. The growing

of corn, possibly supplemented by wheat and oats, and the planting of potatoes and other garden vegetables, together with a little ditching by hand in summer, and perhaps some timber clearing in the winter, rounded out the season's program. Ditching as a legally controlled enterprise received attention as early as 1852, and ditching by hand was reported in Lake County in 1854. But not until steam dredges had been brought into operation in 1884 (3) was there any considerable progress made in drainage. So the ditch may be said to be the key to an understanding of the economy of the Kankakee, of its chronologically and chorographically integrated forms and functions, just as in most regions roads furnish the index to regional development. With systematic ditching came systematic road building and the development of a coördinated ditch–road settlement pattern, which chiefly characterizes the next two periods.

THE RECREATIONIST'S AND THE RANCHER'S KANKAKEE (1880–1910)

The erection of large clubhouses for sportsmen (1878–79); the introduction of large herds of cattle for range feeding by Nels Morris, the Chicago packer, and by others (1880); the use of the steam dredge for the first time in the Kankakee (1884) — these may be taken as basic criteria for the recognition of a new epoch. By this time, we are told, nearly all old trappers had left the marsh. "Rats" and certain other fur-bearing animals were still abundant, but pelts were cheap, though some forms of animal life were becoming scarce if not actually exterminated, as in the case of deer (last one reported shot in 1880). But wild fowl and fish seemed as plentiful as ever and attracted large numbers of sportsmen from far and near, who found the marshes and river a veritable "hunter's and fisherman's paradise." Whereas this form of the recreation industry expressed itself in seasonal boom days for the otherwise thinly settled river territory, the stage was all set for a reclamation program of the marginal marshes. This involved at first ditch drainage, primarily to convert the wild-hay marshes into cattle ranges and grain fields to support a livestock industry.

Ditch digging, now expedited by the steam dredge, also facilitated road building, for the ditch spoil bank itself often served as an elevated roadbed of porous sands and gravel, excellently drained and passable throughout the year. Railroads which were constructed

across the swamp and marshes as early as the 'fifties and the 'sixties merely to connect the older and more settled and better developed Hoosier communities downstate with the coming metropolis of Chicago now actually figured in the Kankakee development along agricultural and recreational lines.

The "Hunter's Paradise"

Railroads thus opened up the once-secluded frontier empire of "fur, fowl, and fin" to the sportsmen of distant cities as well as of communities near by. As individuals and as organized clubs they came in numbers from Boston, New York, Philadelphia, Washington, Chicago, and other large cities. Though the sportsman's presence in the Kankakee is a matter now largely of a most glorious and romantic history, a few geographic landmarks remain: the abandoned Louisville Clubhouse near Baum's Bridge, where stands the historically famous relict houseboat of Lewis Wallace of Ben Hur fame; the Diana Club House near Thayer; the Alpine Clubhouse near English Lake; and the Cumberland Lodge in southern Lake County (see Map 23). The first three represent river sites characteristic of the times. The last has a marginal marsh-island, oak-grove situation.

Several considerations appear to have influenced the clubhouse sites. In the first place, the river itself was a most potent factor, if one may judge from the distribution pattern. It had its own peculiar charm in its beautiful winding and wooded course. By it many a hunter, fisherman, and river resorter entered the region. The general situation gave ready accessibility to both the hunting and the fishing grounds. Clubhouses, however, were not scattered at random along the river, but usually were located at points of vantage representing either favorable dry and elevated sites or transportation advantages of a road or a railroad crossing the river. The combined influence of communication and favorable drainage conditions is illustrated by the agglomeration of clubhouses and tent camps which were at Shelby and at Water Valley. At the latter site, still a popular summer resort, were the Chicago Sportsman Club, the Capitol Club of Indianapolis, the Indianapolis, the Rensselaer, and the Dally clubs, with the Diana Club just south of the river. The Baum's Bridge clubhouse site illustrates by way of general situation the potent influence of the tongue of high and ever-dry sandy upland

"Plainfield" soils, extending southward to the river. This, together with a similar elevated belt on the south side of the river, forms a sort of ridge that bridges the marsh (Map 21). A most important trail of the aborigine, this crossroads of the river, swamp, and marsh was instrumental in making Baum's resort famous. Here located the clubs of Louisville, Pittsburgh, Rockville, Terre Haute, and Indianapolis (27, p. 106).

Among the clubs which established themselves in the Kankakee were the Columbian Hunting Club on Island No. 62 (named after the number of its membership); that of Logansport, Indiana, whose tent camp was pitched on Cornell Island; and the De Guila, Alpine, Prairie, Wallace, La Fayette, and Crawfordsville clubs. The smaller groups and the individual fowler or fisherman used tents, shanties, or cottages. A number were accommodated by farmers living on the marsh margin.

Catering to the general health-, rest-, or recreation-seeking resorters led to the establishment of a number of hotels, as at Thayer.

Reconstructing the former scene of the sportsman's Kankakee, we observe that the swamp rimming the river is sufficiently narrow to act only as a momentary screen to the completely changed yet hardly less charming view of the marsh without. Here, as far as the eye can see, is an expanse of marsh interrupted only by an occasional upland oak grove on a sandy knoll or ridge, or possibly by a cluster of closely set pin oaks rising out of the water, with their characteristic scraggy downward-bending dead branches. Miniature mounds with clumps of grass just emerging from the water betray the somewhat undulating character of the otherwise markedly far-flung flatness of the submerged terrain. Rank sedges and grasses (source of marsh hay) and flags mark the shallower stretches. With these alternate the wild-rice swales; the cattail, spadderdock, and smartweed slough; and the reed and lily ponds, water sites throughout the year.

Domes of earth and flags, the homes of whole colonies of "rats," dot the rims of sloughs, ponds, and poorly defined stream channels. The wild-rice and smartweed fields are the scenes of countless geese and ducks and other wild fowl which find here their ideal harvest by day, and in the neighboring swamp their haven by night. In a rather open spot sits a partly sunken sink-tub, forming an artificial blind screening the hunter. A natural screen almost hides from view the

outlines of a pushboat with the hunter, gun in hand, at the bow. The pusher in the rear propels the boat by probing a long push paddle in the boggy and weedy shallow bottoms of the marsh. In the vicinity of a flag slough is seen another pushboat hunter thrusting a spear into a muskrat mound.

The seasonal arrivals of the various feathered migrants give an added animated aspect to the general picture portrayed above. "In the spring, ducks generally began to arrive around the middle of February, or as early as February 1. Mallards and pintails were first to arrive, followed by teals and bluebills, then spoonbills, and finally the wood ducks, which came about the middle of March. Wood ducks often fed on the timber acorns; others were strictly marsh birds and would not go into the timber swamp except during a storm." [5] "Sand Hill cranes and brant were plentiful in early spring, and later came the jacksnipe, plover, and rail to stay till the water seeped through the sand on the higher marshes, where the prairie chicken could be heard calling at break of day." [6]

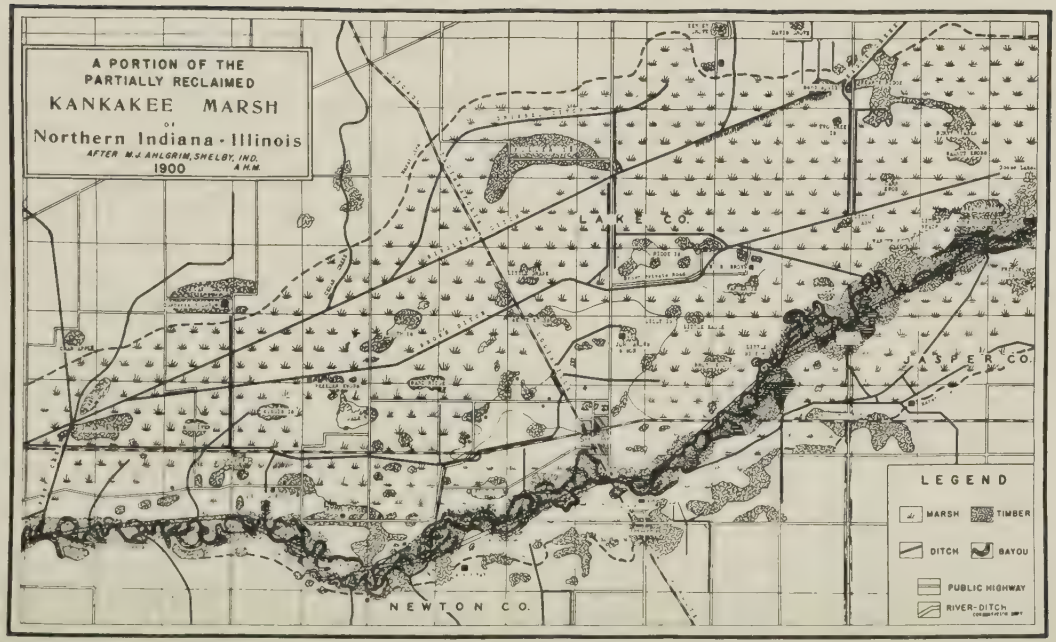
But hunting proved profitable as well as pleasurable. Catering to hunting parties was an important source of income to hotels and certain farmsteads. The tractless morass and swamp also called for pushers who could serve as guides. One such individual conceived the rather ingenious idea of making a geographic survey of the marshes on the ice during the winter (Map 22). Several hundred copies of this map were sold in blueprint form to the visiting hunters, who otherwise might, and did, lose themselves occasionally in the maze of the wild morasses.[7]

[5] Interview with the veteran hunter Mark Anderson of Knox, Indiana, who hunted the Kankakee for fifty years.

[6] Report of another professional hunter of the Kankakee, George Burk, of Valparaiso, Indiana.

[7] Practically all the islands of any consequence in the Kankakee marsh were named, which indicates their geographic importance to the sojourning sportsman and to the native inhabitant. Not only did these named landmarks identify the home, club, and camp sites, but they also served as guideposts to the hunter traveling in an otherwise tractless marsh.

Their nomenclature suggests an interesting study in toponomy. The names characterize many features of the topography and impart a certain amount of personal local color, as is revealed by sampling the several classes of names appearing on Ahlgrim's map and in Werich's work. There are, first of all, the "generic" topographic terms, such as "island," "ridge," "knob," "grove," and "garden." To these, in binomial fashion, are added the "specific" names likewise falling into several categories. Thus we have Indian Garden, French Island; Bissell Ridge, Wheeler Knobs; Little Grape Island, White Oak Island; Goose



Map 22. The Sportsman's Guide Map, by one of the former Kankakee "pushers" (retraced by the author from a blueprint)

The Swamp and Marsh "Natural" Industries

Lumbering

The axe encroaching on the swamp, the sickle advancing into the marsh, the barbed-wire fence enclosing the range, the plow breaking up the prairie sod where the steam dredge had dug wide and deep drainage ditches river-bound — these are additional expressions of the human occupance of this period which we shall now consider.

Lumbering, already started in the last epoch, attained its greatest yet rather restricted development during this period. Among the most enterprising sawmillers at this time was A. H. Ahlgrim, who built sawmills successively near Thayer, Roselawn, and Water Valley. He still resides at Water Valley where he now operates a summer cottage resort.

As early as 1875 logs were rafted down the Kankakee River to Momence, and, since the timber swamp adjoins the river, this would seem to have been an ideal situation. But river rafting did not prove any too practicable, owing to the tortuous and snag-infested channel. The numerous spikes which had to be used to secure the rafts often proved a menace to the sawmiller. In the course of time stationary and then portable mills came to be located at the source of timber, the latter being particularly useful in the small and scattered oak-grove "islands."

The swamp elm, ash, maple, pin oak, and burr oak constituted the chief species marketed from the swamp. On the sand knobs and ridges white oak was extensively exploited. Fence posts and firewood have taken their share of the timber toll. The "setting out of fires" [8] has reclaimed some of the swamp land for agriculture, but extensive tracts of fired timber are unutilized and present a pitiable spectacle of despoliation.

Marsh Haying

Marsh-hay exploitation at this time was a commercial venture on a large scale. With the subsidence of the high spring floods

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Island, Skunk Knobs; Long Ridge, Flat Island; Shanty Island, Bridge Island; Bogus Island, Island Six to Two.

Another set of terms identified water forms of the marsh, swamp, and river, for example: Flag Pond, Wild Cat Swamp, Sandy Hook Creek, Cornell's Bayou, Pottawatomie Ford, Frenchman Slough, South Marsh, Devil's Race Track.

[8] Said by Richard Lieber, former head of the Conservation Department of Indiana, to be a typical "Hoosierism."

about the first of May the wild sedges and grasses were ready to be cut in July and August. What was not summer-pastured, or fed locally as winter forage, was baled by large steam presses and exported. The varieties of short and long, tender and tough sedges and grasses adapted the hay to various uses. From the upper shallower marsh sites and along the "islands" was cut the shorter, tender, more succulent, and nutritious feeding hay; the lower deeper marshes yielded rank and tough growths, which were shipped, to Chicago, for example, as bedding or packing hay.

Stock Grazing

The marsh-hay pastures and the "island" oak groves invited a cattle economy which was developed first and foremost by Nels Morris, the Chicago packer. Practically all the true Kankakee marsh and swamp lands of Jasper County and northeast Newton County, totaling 23,000 acres, were taken over by him. Thousands of head of cattle, many from Texas, were shipped in and grazed on tracts fenced into units the size of a section or so, imparting the aspect of a western ranch with its picturesque professional cowpuncher.

Other ranches included the well-known Brown estate in southern Lake County, partly protected from flood by a privately constructed dike or "levee"; and another ranch of about 5,000 acres near Thayer, Newton County.

THE RECLAMATIONIST'S AND THE RESORTER'S KANKAKEE (1910—)

The Kankakee is a quandary. If one were to ask today "What does the Kankakee represent?" the answer would probably be one of two opposing types: (1) It represents a land that "God forgot to finish," a man-reclaimed area of extraordinary fertility; (2) It represents a manhandled marsh, a failure as a reclamation project, a substitution of unproductive lands for the most ideally adjusted wild-life forms of plant and animal, so essential to the nation's conservation program. A survey of the physical and cultural setup should help in clarifying the situation. The regional quality of the Kankakee may be assayed (1) by comparing it with its neighboring morainal uplands and (2) by taking a qualitative-quantitative inventory of the resources of its component divisions.

The panoramic map (Map 23) may be said to express the sum and substance of the author's contribution to Kankakee chorography. Together with explanatory notes it records the essential results of both personal field survey and literary research. Its crop-cover analysis and land-soil synthesis are offered as a more or less self-contained unit.[9] It remains to interpret these data along with the questionnaire interviews in terms of the present human occupance and economy.

The area as delineated represents the river territory of some 620 square miles embraced within the so-called "Kankakee Grain and Pasture" agricultural division of northwest Indiana. This division practically coincides with the sandy "Maumee–Plainfield–Newton–Muck" soil province, to which the Kankakee proper adds the Swamp. Once an ancient lake bottom, the far-flung Kankakee terrain, interrupted only locally by sand knobs and ridges, conduced to readiness of cultivation in large field units. Quarter or half sections of corn divided by few fence lines are not uncommon. Large level field units favor tractor farming, and make for large farms, many of them a half section or more, as compared with the quarter-section farm on the rolling rimming moraine. But large farms involve large investments, particularly in the case of virgin bottom land held at initial high figures and subject to drainage assessments. The result is that the larger Kankakee farms show an extraordinarily high percentage of tenant operators, as high as 85–90 per cent in some localities, whereas on the neighboring uplands one half or more of the farms are operator-owned. Combined frequently with uncertain or short-term leases, such a system conduces to a more or less exploitative type of grain farming, without proper regard for the place of the animal industries in helping to maintain soil productivity. Once famous for its large ranches of beef cattle, the Kankakee today is noted for its cereal culture. Livestock consists chiefly of small dairy herds normally ranging from six to a dozen head and of swine about twice that number. The swing in latter years to dairying in the form of whole-milk production reflects the proximate position of the Kankakee with respect to Chicago. Its more distant position and poorer quality of pasture, however, put it at a certain disadvantage as against the closer competing areas.

[9] Natural cover and crops are represented by superimposed colors on the author's hand-colored map.

The Physical Setting

Climate

As indicated in the introduction, the Kankakee lies within the Köppen Dfa type of climate (Map 19). However, it assumes practically a borderline position between the severe-winter Dfa and the mild-winter Cfa types, the average temperature of only one month falling below 26.6° F., the critical figure used to define the D–C boundary. With a total of nearly ten inches of summer rainfall (two inches above the critical corn figure), in addition to an advantageous high water table, and with a growing season isotherm of over 71° F. (5° above the critical corn temperature), the climate is generally well suited for corn, the chief culture, except for certain frost hazards, as pointed out below.

Although statistical data for near-river locations are not available, those of Wheatfield are considered quite representative of general marsh conditions; the station has essentially a marsh situation and elevation, though its location is somewhat marginal to the marsh proper.

AVERAGE TEMPERATURE AND PRECIPITATION DATA OF WHEATFIELD, INDIANA (19)

Length of record, 14 years

Average monthly temperature for the year, 49.7° F.
Total average annual rainfall 33.69 inches

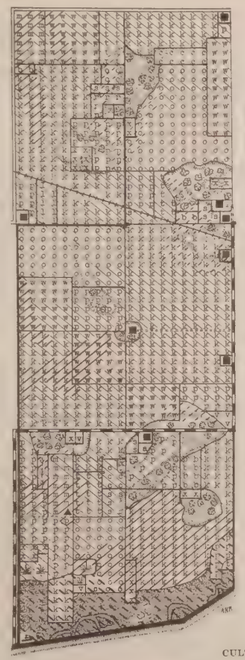
	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Temperature .	28.2	28.8	38.8	48.5	58.7	69.2	73.4	71.2	65.0	53.2	37.6	28.3
Rainfall	1.82	1.28	2.61	3.74	3.30	3.60	3.04	3.10	3.55	2.91	2.25	2.49

Comparison of the monthly, seasonal, and annual temperature and precipitation figures of Wheatfield with those of a typical upland border moraine station, like Valparaiso, about twenty miles due north, reveals a very close parallelism of climatic conditions. A noticeable distinguishing feature of some climatic significance, however, is found in the comparative frost data of the two stations, which are as follows:

Stations	Length of record in years	Average date of last frost in spring	Average date of first killing frost in autumn	Growing season between frosts in days	Latest date of killing frost in spring	Earliest date of killing frost in autumn
Valparaiso	16	May 4	Oct. 11	160	May 28	Sept. 11
Wheatfield	14	May 12	Oct. 5	146	June 16	Sept. 11

A REGIONAL SYNTHESIS OF THE KANKAKEE

FORMS OF THE NATURAL ENVIRONMENT



LANDFORM

Sand "islands" or dunes rising typically 5 to 15 feet (some 20–30 feet) above the otherwise markedly flat landscape

RELICT DRAINAGE

Remnant meanders of the original Kankakee River

SOILS

(For description of types see the map)

- Plainfield
- Newton
- Maumee
- Swamp
- Muck

NATURAL COVER ASSOCIATIONS

(Partly pastured)

(For description of associations see the map)

- Maple–ash–elm
- Pin oak–black oak
- Willow–maple–cottonwood
- Black oak–white oak
- Marsh sedge and grass

FORMS OF THE HUMAN OCCUPANCE

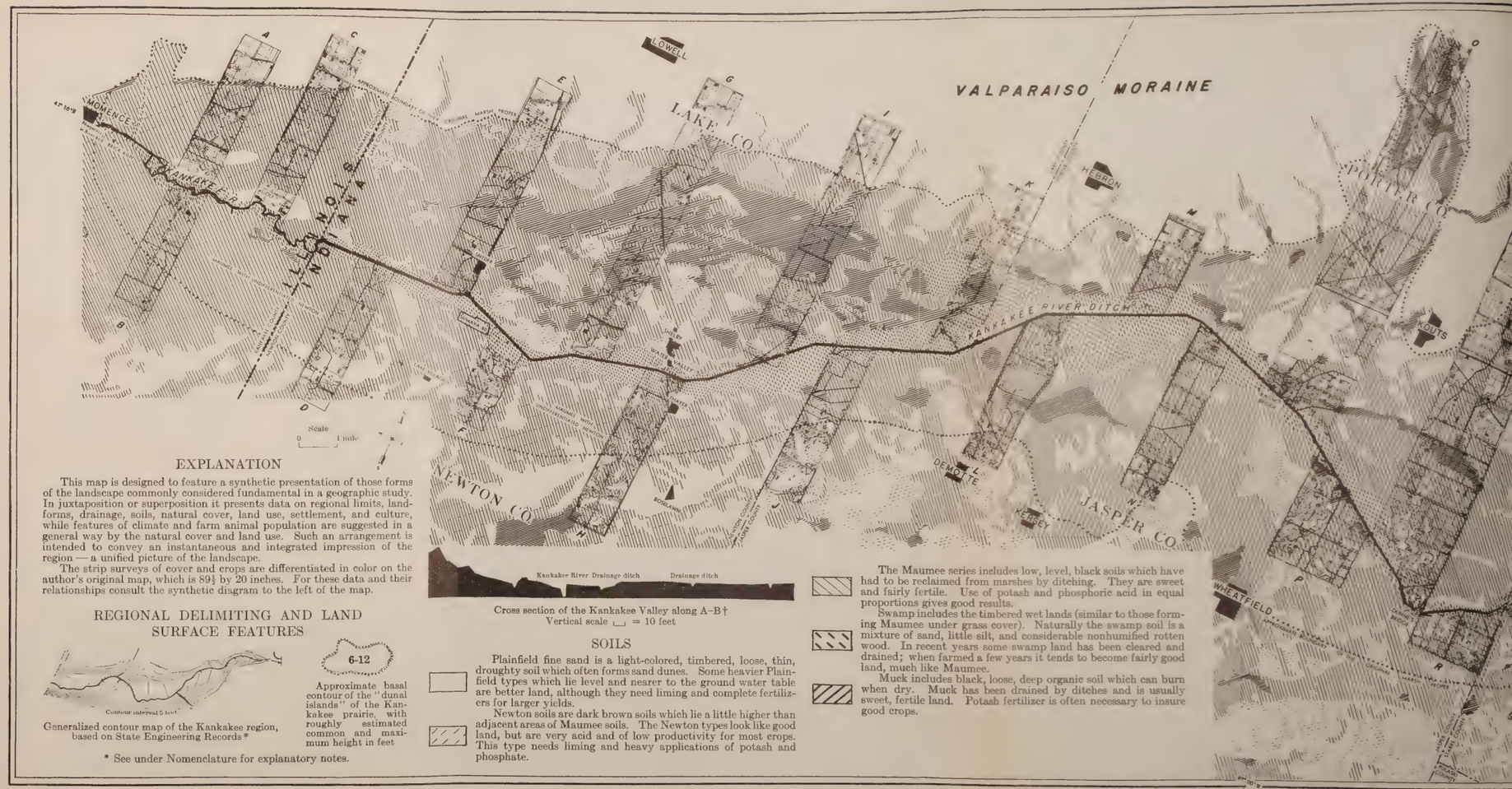
CROPS

k	Corn
o	Oats
w	Wheat
r	Rye
l	Barley
b	Buckwheat
t	Timothy
c	Clover
a	Alfalfa
s	Soybeans (or cowpeas)
m	Mint
v	Truck (vegetables)
p	Plowable pasture
x	Fallow or waste land

CULTURE

- Farmstead
- Resort cottage(s)
- Mint still
- Gravel or paved road
- Primary dirt road
- Secondary dirt road
- Railroad
- Reclamation ditch
- Kankakee River and spoils bank

This geographic pattern is designed to supplement the uncolored Chorography map by supplying cover and crop data, and graphically to portray a regional synthesis of the Kankakee. It illustrates the characteristic forms of the landscape, their proportionate areal spread, and the relations of the various crops to each of the several soil types, as determined by a quantitative analysis of thirty-two strip surveys, embracing approximately twenty-five per cent of the region. The diagram reveals a high percentage correlation in each of the following human adjustments: farmstead–sandy, forested "islands"; pasture–drainage ditch; soybeans, rye, natural pasture, waste land–Plainfield, Newton; corn, oats, wheat–Maumee; mint–Muck; resort–Swamp.



EXPLANATION

This map is designed to feature a synthetic presentation of those forms of the landscape commonly considered fundamental in a geographic study. In juxtaposition or superposition it presents data on regional limits, landforms, drainage, soils, natural cover, land use, settlement, and culture, while features of climate and farm animal population are suggested in a general way by the natural cover and land use. Such an arrangement is intended to convey an instantaneous and integrated impression of the region — a unified picture of the landscape.

The strip surveys of cover and crops are differentiated in color on the author's original map, which is 89½ by 20 inches. For these data and their relationships consult the synthetic diagram to the left of the map.

REGIONAL DELIMITING AND LAND SURFACE FEATURES

Generalized contour map of the Kankakee region, based on State Engineering Records *

6-12

Approximate basal contour of the "dunal islands" of the Kankakee prairie, with roughly estimated common and maximum height in feet

* See under Nomenclature for explanatory notes.

Cross section of the Kankakee Valley along A–B†
Vertical scale ⌊ = 10 feet

SOILS

Plainfield fine sand is a light-colored, timbered, loose, thin, droughty soil which often forms sand dunes. Some heavier Plainfield types which lie level and nearer to the ground water table are better land, although they need liming and complete fertilizers for larger yields.

Newton soils are dark brown soils which lie a little higher than adjacent areas of Maumee soils. The Newton types look like good land, but are very acid and of low productivity for most crops. This type needs liming and heavy applications of potash and phosphate.

The Maumee series includes low, level, black soils which have had to be reclaimed from marshes by ditching. They are sweet and fairly fertile. Use of potash and phosphoric acid in equal proportions gives good results.

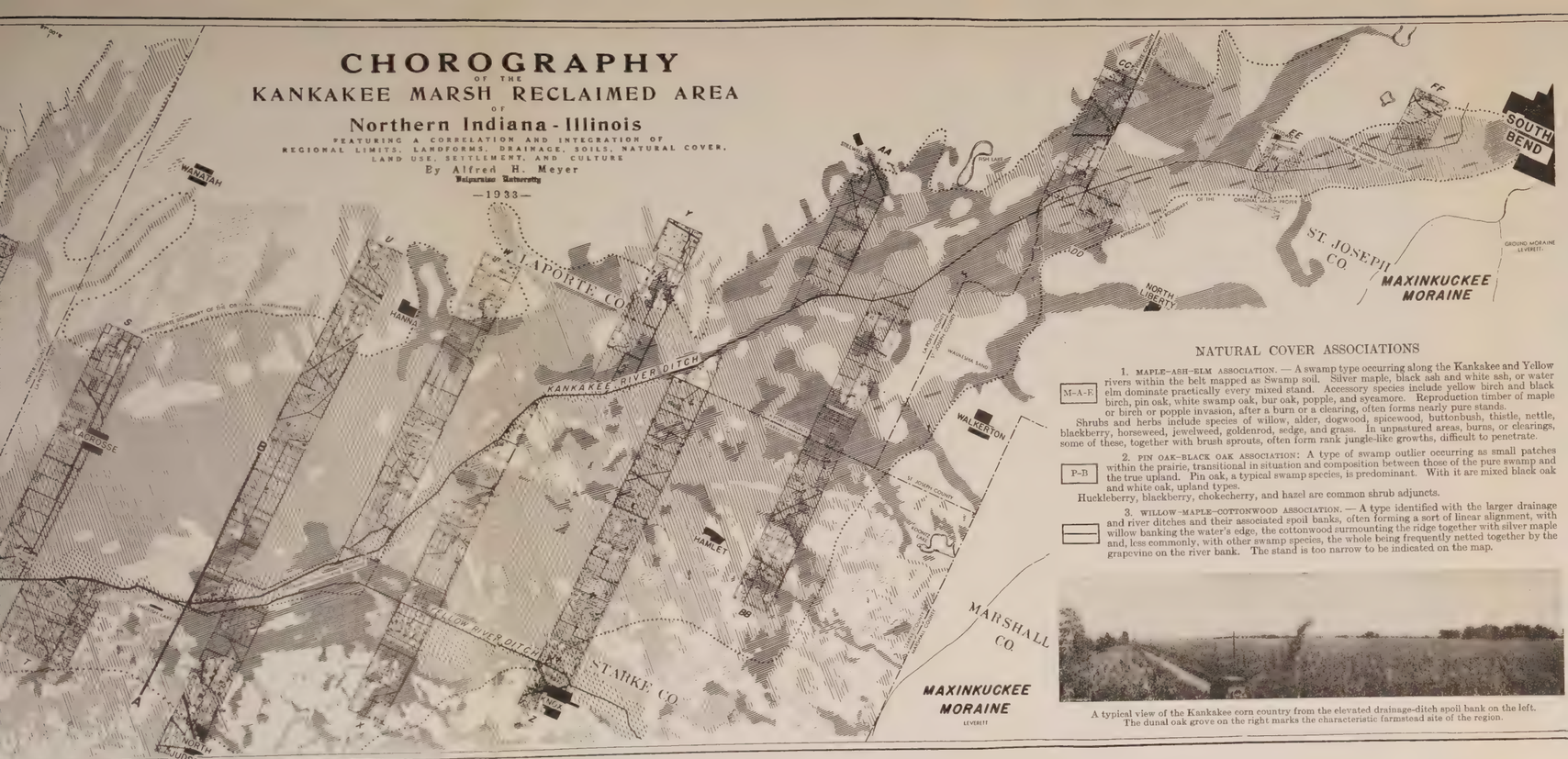
Swamp includes the timbered wet lands (similar to those forming Maumee under grass cover). Naturally the swamp soil is a mixture of sand, little silt, and considerable nonhumified rotten wood. In recent years some swamp land has been cleared and drained; when farmed a few years it tends to become fairly good land, much like Maumee.

Muck includes black, loose, deep organic soil which can burn when dry. Muck has been drained by ditches and is usually sweet, fertile land. Potash fertilizer is often necessary to insure good crops.

CHOROGRAPHY
OF THE
KANKAKEE MARSH RECLAIMED AREA
OF
Northern Indiana - Illinois

FEATURING A CORRELATION AND INTEGRATION OF REGIONAL LIMITS, LANDFORMS, DRAINAGE, SOILS, NATURAL COVER, LAND USE, SETTLEMENT, AND CULTURE

By Alfred H. Meyer
Valparaiso University
—1933—



NATURAL COVER ASSOCIATIONS

M-A-E — 1. MAPLE–ASH–ELM ASSOCIATION. — A swamp type occurring along the Kankakee and Yellow rivers within the belt mapped as Swamp soil. Silver maple, black ash and white ash, or water elm dominate practically every mixed stand. Accessory species include yellow birch and black birch, pin oak, white swamp oak, bur oak, popple, and sycamore. Reproduction timber of maple or birch or popple invasion, after a burn or a clearing, often forms nearly pure stands.

Shrubs and herbs include species of willow, alder, dogwood, spicewood, buttonbush, thistle, nettle, blackberry, horseweed, jewelweed, goldenrod, sedge, and grass. In unpastured areas, burns, or clearings, some of these, together with brush sprouts, often form rank jungle-like growths, difficult to penetrate.

P-B — 2. PIN OAK–BLACK OAK ASSOCIATION: A type of swamp outlier occurring as small patches within the prairie, transitional in situation and composition between those of the pure swamp and the true upland. Pin oak, a typical swamp species, is predominant. With it are mixed black oak and white oak, upland types.

Huckleberry, blackberry, chokecherry, and hazel are common shrub adjuncts.

3. WILLOW–MAPLE–COTTONWOOD ASSOCIATION. — A type identified with the larger drainage and river ditches and their associated spoil banks, often forming a sort of linear alignment, with willow banking the water's edge, the cottonwood surmounting the ridge together with silver maple and, less commonly, with other swamp species, the whole being frequently netted together by the grapevine on the river bank. The stand is too narrow to be indicated on the map.

A typical view of the Kankakee corn country from the elevated drainage-ditch spoil bank on the left. The dunal oak grove on the right marks the characteristic farmstead site of the region.

Sand sedges and grasses, Equisetum, milkweed, cinquefoil, and butterfly weed represent but a few of the large variety of xerophytic or other upland types of herbs occurring on the dry spoil banks and functioning in part as sand binders. In the drainage ditch below, the growth of aquatic sedges and grasses, species of bladderwort, algae, duckweed, water plantain, and cattail sometimes proves a troublesome current-retarding and ditch-filling factor.

B-W — 4. BLACK OAK–WHITE OAK ASSOCIATION. — A type forming characteristically fixed dune groves so conspicuous in the otherwise flatlish and naturally featureless landscape, or constituting the upland timber of the prairie margin. Either because of natural conditions or because of the removal of the white oak, black oak is nearly always the dominant and, sometimes, the exclusive species. Hickory is significant in only a few localities; occasionally red oak occurs. Pin oak characteristically forms a very narrow girdle at the base of the wooded knoll or sand ridge.

Dwarf huckleberry, blueberry, and blackberry are shrub associates of this timber type.

5. MARSH SEDGE–GRASS ASSOCIATION. — This type, once predominant over entire sections, today represents hardly more than a mere relict formation. A few local poorly drained pockets or ill-defined stream courses are characteristic sites. It is shown on the map by the conventional marsh symbol.

NOMENCLATURE

The specific qualitative-quantitative inventory of dominant and secondary tree species in a particular locality is indicated by a code. An initial capital letter, in a few cases with an additional consonant, designates the species. The sequence of letters in a group signifies a descending order of species dominance. Common dimensions are indicated by one or more small figures placed on top of the letter symbol so spaced as to apply to a particular species or to the group. Density of stocking, or stand of timber, is shown by underscoring.

ABBREVIATIONS

A — Ash	M — Maple	R — Red oak
B — Black oak	P — Pin oak	S — Swamp white oak
Br — Birch	Pd — *Populus deltoides* (Cottonwood)	W — White oak
C — Cherry		Wl — Willow
E — Elm	Pt — *Populus tremuloides* (Aspen)	
H — Hickory		

DIAMETERS

1—0–3″ 2—0–6″ 3—6–12″ 4—12–18″

TYPE OF STOCKING

— Heavy = Medium ≡ Thin

INTERPRETATION OF THE CODE

3 2 1 / B W H — Black oak, ranging 6–12 inches in diameter, dominant; smaller number of white oak ranging 0–6 inches; a still smaller number of hickory, 0–3 inches; the stand as a whole of medium stocking

2 / M A — Maple dominant; maple and ash ranging 0–6 inches; stocking, thin

* After T. M. Bushnell, "Physiography of the Kankakee Region," *Proceedings of the Indiana Academy of Science*, 37 (1927): 141–142.

† Adapted after a section in "Biological Survey of the Kankakee River Bottoms," by the U. S. Department of Agriculture, based on State Engineering Records, January, 1932.

USE OF FARM LAND

LEGEND

Grain: corn, wheat, oats, rye, barley, buckwheat; Hay: timothy, clover, alfalfa, soybeans (or cowpeas); Truck: onions, miscellaneous; Pasture: potential or permanent pasture, plow pasture; Mint. (In the original map all these uses are differentiated by colors.)

Wild hay

x — Fallow or waste land

pl — Plowed land at time of mapping

SETTLEMENT AND CULTURE

LEGEND

Primary road, approximately 55 per cent improved

Secondary road

Railroad

Drainage ditch

Mint still

Town or city

Farmstead

X Shanty

Abandoned house

School

Church

Cemetery

C Clubhouse

P Recreation park

State game preserve

8c — Rows or groups of resort cottages along river, with approximate number of cottages

SOURCE MATERIAL. — Except in the cases of Jasper and La Porte Counties, Federal- and State-issued maps were the source of soil data. Through the courtesy of Dr. T. M. Bushnell, in charge of soil survey at the Purdue University Agricultural Experiment Station, arrangements were made for a soil tracing of the unpublished Jasper County field sheets; Mr. H. P. Ulrich, engaged in the resurvey of La Porte County, under Dr. Bushnell's direction, supplied an outline soil map of that county, basing the eastern part on air photographs. For the contributions of these individuals, and particularly for the interest shown in and attention given to the problem of soil correlation of the several counties by Dr. Bushnell, the author is greatly indebted.

Grateful acknowledgment is also made to Miss Elizabeth Rechenberg of the Valparaiso University staff in a number of determinations of plant species. For general professional guidance thanks are extended to the several members of the Geography Department of the University of Michigan, Dr. K. C. McMurry, chairman and special adviser.

The shorter frost-free season in the Kankakee as compared with the neighboring upland is no doubt chiefly due to air drainage, locally influenced further by muck soil.

Subsoil

The sandy and gravelly substratum deposited in the original Kankakee lake basin has proved at once the boon and the bane of its agriculture. Facilitating subsurface drainage, the light and porous subsoil is responsible for heavy leaching. Especially is this a vital factor when one considers the limited rôle livestock plays in the extensive cereal type of farming, in which animal manures are quite negligible. Consequently fields planted to corn are now almost regularly fertilized (about 100 lb. of commercial fertilizer to the acre), as is practically true also of wheat.

Soil

The dozen or more different soil types, represented in part by a variable classification and scale in the several counties, may be reduced to a regional basis of five serial units: Plainfield, Newton, Maumee, Swamp, and Muck. Their areal spread is indicated below. Maumee, rated in general as an all-round good soil, comprises about three fifths of the Kankakee area, whereas Muck, covering an additional seventh, is a fertile organic soil well adapted to special crops, such as mint, corn, and certain truck products. The remaining approximate fourth embraces Plainfield and Newton, mostly lean, light-textured soils, and the Swamp, mostly representative of burned or partly cleared timber wastes.

Drainage System

As pointed out above, the chorographic development of the Kankakee is a function of the drainage ditch, without which the expansion of agriculture would have been impossible.

Dug by hand in pioneer days, then by oxen and horses, and finally by steam dredge, introduced at the beginning of the last epoch (1884), drainage ditches were extended farther and farther from the marsh margin into the river swamp. The Kankakee River itself finally was straightened in Indiana, first in its headwaters and then all the way to the state line (1906–17). In addition to the drainage ditch, the reclamation system locally includes tile drainage and levee protection (for example, Brown Levee in southern Lake County).

UPPER SECTION JOINS LOWER SECTION AT "A-B-C"
KANKAKEE RIVER, ILL. & IND.
U. S. ENGINEER OFFICE, CHICAGO, ILL., AUG. 7, 1933
DRAINAGE AND CIRCULATION PATTERNS
OF THE KANKAKEE MARSH
GOVERNMENT MAP
LEGEND
DRAINAGE DITCH
HIGH WATER LINE, 1927
ROAD
RAILROAD
EXPLANATION
DRAINAGE AND HIGH WATER
LINES HEAVILY RETRACED
BY THE AUTHOR

Map 24

The most remarkable fact about the present drainage setup is its marked artificial character. This is strikingly expressed by the rectilinear pattern of the numerous ditches with straight angular courses and profiles (Map 24), frequently accentuated by high-banked spoil ridges flanking the ditches.

The reclamation program utilized in part the original natural channels of stream drainage, which were straightened and enlarged. Much more ditch mileage, however, is represented in the newly dug trenchlike drainage lines which in large areas conform to the regularity of a road pattern. Together these form an elaborate dissection of the Kankakee plain, in which practically each section lies within only a mile, or a mile and a half, of a drainage ditch, whereas the majority of sections regularly have one and occasionally two ditches transecting or flanking them.

Three general classes of drainage areas and associated types of drainage features may be recognized:

(1) Along the river is the swamp, for a convenient boundary of which we may take the high water line shown on Map 24. Within this area, which is generally still underdrained and subject to periodic overflow, we have first of all the Miller–Place–Marble–Williams' ditches. Jointly they represent the dredged equivalent of the original meandering Kankakee. The straightened and deepened and widened channel follows only the most general trend of the early river and is for the most part flanked by high spoil banks. The digging of the big ditch and the dumping of the spoil material have all but obliterated the original river meanders, bayous, and oxbows, though occasionally one has been spared.

Associated locally with the main ditch are levees and parallel relief ditches, which could almost be regarded as a part of the river system; tributary swamp feeders enter the main line of drainage mostly at right angles, in trellis fashion.

(2) The marginal marsh whose drainage lines characteristically follow the parent natural stream channels have preserved somewhat the original dendritic pattern. These ditches, in their headwaters at least, follow rather closely the trend of the ancestral creeks which descended the marginal moraines and debouched their waters into the marsh.

(3) Finally, ditches of a third class may be regarded as artificial

"extended consequents," which lead the water from the marginal marsh ditches into the main channel.

The lack of sufficient fall directly riverward resulted in the peculiar deflection westward of these lower marsh drainage courses. Examples of these drainage units running almost parallel to the river ditch are the Singleton and Brown ditches in Lake County and the Hodge ditch in Jasper County.

Ditches commonly are eight, fifteen, and twenty feet in width; a number of them are as much as a half chain wide. The river ditch in its lower course ranges from one and one-half to two chains in width. In addition, almost an equal space is occupied jointly by the berm and the spoil bank, although in some places the excavated material of the smaller ditches is leveled off and becomes part of the cultivated field.

Agricultural Forms

Crops

"Corn is King" in the Kankakee, apparently occupying more acreage than all other cultivable crops together. Oats ranks next, followed by wheat. Both plow pasture and forage crops are close rivals of wheat for third place. This order likewise expresses the normal sequence of crop rotation (c-o-w-p), though the cycle may stop with three or two crops. Thus plow pastures are renewed normally about every fourth year.

Cereal crop yields on the better Kankakee soils (Maumee–Muck - Swamp) probably in general run from 25 to 50 per cent higher than on the bounding uplands, 35 to 40 bushels of corn to the acre being not uncommon. But the soils generally, as pointed out above, show a marked tendency toward depreciation. Thus they express a condition of both strength and weakness. Particular soil adaptations are discussed below under the several soil-land heads. In addition to these influences, several crop concentrations are noted as influenced by factors quite independent of any particular soil type. The author's survey reveals a marked regional differentiation in the amount of acreage devoted to wheat in the eastern half as compared with the western. Proportionately much more wheat is raised east of La Crosse, or the Porter-Lake and Jasper-Starke county lines, than west of them. This condition seems to be related to the higher position and hence the drier condition of the upper valley.

Mint is confined to the Muck areas or mucky phases of the Maumee east of the Hanna–North Judson line. Though the Kankakee soils collectively and individually are peculiarly well adapted for growing truck products, proximity to consuming centers or storage and marketing facilities results in local concentrations, such as at De Motte, North Judson, and particularly at South Bend.

The general friability of the Kankakee soils, like the levelness of the terrain, facilitates plowing and cultivation. Sticky clays or cloddy textures are practically unknown. On the other hand, certain types, such as the Plainfield or the lighter Muck, are so light that they will "blow." Roots of plants may thus be exposed or the whole plant dislodged. Furthermore, muck dust makes cultivation on windy days unpleasant for both man and beast. A farmer on muck ground remarked: "There was a time when we 'drowned out'; there are times now when we 'freeze out'; and then again we may 'blow out'."

The general conditions of the subsurface drainage appear quite satisfactory (25). It is only natural, however, that in a dry season the ground water table level should be found too low on the sandy uplands, and in the wet season too high on the low swales. It appears also that, when droughts do occur, the crops on the upper sandier areas may "burn up" in a day or two, whereas on the bordering moraine uplands the effects are felt gradually.

Having to reckon with but few surface obstacles, except in the swamp, the ditch-digging program was primarily concerned with getting sufficient fall, an important item in a nearly level country where the coarse sandy sediments have a tendency to fill up the ditch. Associated with this phenomenon, the growth of cattails, bladderwort, and other aquatic forms check the current and, together with sand deposits, clog the drainage lines. Either of these conditions in time necessitates recleaning.

Pasture and Waste Lands

The Kankakee is identified with the so-called Grain and Pasture region of Indiana. In the Kankakee reclaimed area proper about one eighth of the cultivable area is in plow or rotation pasture, and with grain shares the better lands, the Maumee and the Muck. Much of the Kankakee pasturage, however, is relegated to the marginal, light, rolling, and partly wooded Plainfield and closely asso-

ciated Newton. As much as 25 to 40 per cent of the Plainfield groves is pastured. This type of native pasture is of rather inferior quality, with a carrying capacity of one grazing unit to 5–10 acres.

A much smaller percentage of the Swamp is used for pasture on account of the inadequate drainage and the extensive cover of timber, brush, and rank weeds.

Contrasting with the regular rectangular grain fields and plow pasture, the outline of the native pastures is notoriously irregular, bounding a Plainfield ridge or knoll or enclosing an irregular brush or stump clearing in the swamp.

While most of the Swamp and much of the Plainfield timbered areas represent practically waste land, the "broken" marsh and swamp areas have an insignificantly small acreage lying idle, as indicated by an x on the Chorography map (Map 23). The small widely scattered units amount to hardly three sections of all those mapped, or barely two per cent of the whole cultivable area of the inner Kankakee basin. Even some of this represents only temporarily fallow fields.

One of the most singular expressions of agricultural adjustments arising from the ditch-digging program in the Kankakee is the appropriation of ditch water for livestock. A large number of ditches are sufficiently below the ground water table to offer a more or less permanent supply of good water, though stagnation and heavy iron flocculations sometimes result when the water table gets too low, or when partial clogging of the ditch occurs, as mentioned above. But ditches were not designed to be "natural watering troughs" for stock to trample around in; in fact, there appears to be a regulation against the use of the drainage ditch for this purpose. At any rate, in nearly every case the ditch is outside the regular pasture bounds, and its water is made available to stock by extending the fence at certain points part way into the ditch.

Settlement and Circulation

Farmhouses average somewhat less than three to the square mile, or a total of some 1,800 for the region. Unlike the more or less even distribution on the marginal moraine country, the occupance pattern shows marked local concentrations, as will be brought out in discussing the respective types below.

The reclamation of the original Kankakee on a large scale was

made possible mainly through the relatively few but extensive holdings of land companies or individuals who offered the land for sale undeveloped or improved. The ready-made farm unit tended to assume a standard type — a half section of land with a frame T or L structure of seven or eight rooms, or the cheaper square double-story type. As the Kankakee became more settled variable types were introduced.

More than half of the farmsteads of the Kankakee are located on a hard-surfaced highway of some kind, commonly of gravel or macadam, or, as in the case of superhighways, of asphalt-macadam or concrete. Only very few of the remaining farmers are more than a mile from an improved road. But under modern drainage conditions even the ordinary "dirt" road is seldom impassable, owing to the sandy base. The ready subsurface drainage, combined with the frequent availability of ditch-dredged material for elevating the roadbed, has proved a great asset to the Kankakee road-building program.

Towns

With few exceptions the towns, as shown on Map 23, may be said to belong to the bordering moraines rather than to the inner basin proper. Their marginal position clearly is determined by the barrier influence of the early "marsh" to encroaching settlements.

Of the score of settlements that rim the basin, only one, that of South Bend at the head of the valley, is a ranking industrial community; it has a population of over a hundred thousand. Several of the larger towns have a population of from one to two thousand; most of them have less than five or six hundred inhabitants.

Grain elevators, a few warehouses for storage of truck products (in the east), and an occasional light industry, such as a pickle-preserving plant at Knox, enter into the simple extracommercial core setup of the Kankakee trading centers.

Regional Subdivision

The Kankakee region may be regarded as made up physiographically of only two consolidated divisions: a narrow but practically continuous timber swamp in the river bottoms and the extensive marsh prairie of the flat-floored valley. A very general distinction may also be recognized topographically (geographically) between the eastern and western halves in that the former lies higher, has a

greater average width but a narrower and finally disappearing swamp; features larger muck areas, with mint culture (altogether absent in the west); and produces proportionately more wheat and truck. On the other hand, practically all the river resorts and amusement centers were and still are in the western half.

Basis for Areal Differentiation

Except for the general divisions given above, the Kankakee does not appear to lend itself to a simple dissection into unified homogeneous units. Subregional treatment rather involves a recognition of a unit form as consisting of small patches of the landscape related in structure and origin, however discontinuous and dispersed they may be. The basis for such areal differentiation is found in the diverse land-soil formations of the valley. Comprising a dozen or more soil types, the soils for purposes of a regional classification may be reduced to five structural classes reflective of land surface as well as soil characteristics — Plainfield, Newton, Maumee, Swamp, and Muck.

Landform and Land-Use Patterns

Plainfield: The Farmsteaded "Island." — The sandy and rolling Plainfield is at once next to the least and yet the most important topographic unit in the Kankakee. Aside from the Swamp, it embraces by far the greatest percentage of untilled land; however, it can claim more farmsteads per unit area than the other four units combined.

Occurring in the form of islands in the early wet marsh, the Plainfield still forms the most striking natural element of the prairie landscape in terms of both landform and natural vegetation. As indicated on Map 23, the insular units are quite regularly distributed and range in size from a mere knob large enough to accommodate a single small farmstead up to a square mile or more in area. The Plainfield as mapped includes a small amount of heavier clayey phases that do not form conspicuous rises. The areas definitely ridged or elevated are included in a dotted line on the map, representing the basal contour above which the roughly estimated average (or common) and maximum heights are recorded in feet. Thus an inventory of a score of recorded values for each of five counties shows an average of 5 and 10 feet for common and maximum dunal heights,

respectively. Small knobs generally do not rise much over 5 feet; the higher ridges run from 15 to 20 feet, and, in extraordinary cases, from 30 to 35 feet in height. These elevated tracts assume the form of small circular or oval mounds (H 4, U 31); or long, narrow linear ridges (L 11, N 4); or very irregular outlines (D 19, V 5).[10]

Forming the earliest sites of cultivation as well as habitation, the Plainfield is today agriculturally noted chiefly for its woodlot or herb pastoral economy. It is the only landform, aside from the Swamp, in which the area devoted to grazing is practically equal to or even greater than that devoted to wheat and oats combined, or to corn culture. Representing only about one fifth of the area of the fertile Maumee, it has nearly one half as much pastoral acreage. However, its grazing value, as was pointed out above, is much inferior, and in part represents actually waste land. Whereas the carrying capacity of the Maumee is probably around $1\frac{1}{2}$–2 acres per head, the Plainfield requires 5–10 acres. After the cereals beans, rye, forage crops, and truck follow in importance. In view of the general droughtiness of the lighter soils, which makes the growing of other forage and green manure crops difficult, soy beans (and locally cowpeas) prove a godsend to the sandy areas. Proportionately, the Plainfield has five times as much acreage in soy beans as the Maumee. The larger Kankakee soil province ranks first in the state in rye production. A characteristically poor soil crop, rye practically coincides in its distribution with the Plainfield.

The sinuous ridges of the Plainfield break up the horizontal as well as the vertical monotony of the Kankakee landscape. Cultivated fields are interrupted, winding fences bound the ridge pastures, and extensive unoccupied areas in one section (D 19) contrast with the numerous small closely set farmstead groves in another section (T 10). Plainfield houses average eight to the square mile and show a tendency to be agglomerative (E 16, O 25, W 27, 34, 3). Though the former necessity for living here has passed owing to adequate drainage, the prairie "islands" supply natural shade trees and make for dry farm lots, even in the wettest season. Besides they command a view above and beyond the surrounding "cornscape."

Maumee: The Kankakee "Cornscape." — In terms of area or productivity the Maumee exceeds in importance not only any other

[10] Letters and numbers refer to strip and section location on the Chorography map (Map 23).

Kankakee form but all the others combined. It is the fundamental or basic structural unit of the Kankakee. Generally characterized by large continuous units, it is especially dominant in the eastern half, where, in the former "Grand Marsh" area, or southern La Porte County, and its adjacent parts in northern Starke County, it forms only a slightly interrupted unit of some 150 square miles, or nearly one fourth of the whole marsh.

Consisting largely of sandy loams and aggregating some three fifths of the whole area, it has a relative productivity several times this ratio. And so the Maumee may be truly said to be the "key to Kankakee agriculture." It seems quite equally adapted to the growing of all the Kankakee crops.

While averaging only two, or only one fourth of the number of farmhouses per square mile as compared with the Plainfield, the Maumee outranks the Muck–Swamp combined two to one. Since it represents the later lands in the Kankakee to be reclaimed, one would not expect to find remnants of pioneer homesteads on this type, as in the case of the Plainfield and the Newton.

Newton: The Plainfield–Maumee Transition. — The Newton assumes an intermediate classification between the Plainfield and the Maumee in essentially all soil and topographic features. Lying characteristically between the higher Plainfield and the lower Maumee, it partakes now of the former characteristics, now of the latter, with transitional phases difficult to identify definitely with the one or the other.

Generally light in texture, similar to certain phases of the sandy Plainfield, the typical dark brown of the Newton is suggestive of the Maumee. Its natural cover now may partake of the Plainfield oak association, and again may represent a transition mixture of swamp pin oak and upland black-white oak, or occur in the form of a swamp outlier of pin oak. Marsh herb no doubt also entered locally into the original composition.

The crop-distribution analysis seems to suggest nothing much out of the ordinary, except a disproportionately large acreage of oats.

Averaging per unit slightly less than half the number of Plainfield farmsteads, the Newton does show definitely the effects of its elevation above the Maumee in having nearly twice as many houses relatively as the latter.

Muck: The Mint Formation. — Constituting about 15 per cent

of the area, the Muck occupies the former sites of shallow lake basins and swales and tributary valleys more or less permanently covered with standing water in which grew cattails, reeds, flags, aquatic sedges and grasses, and other forms of vegetation. The high organic content of "raw" muck (or peat) is illustrated by the shrinking which results when a farmer sets out a fire on this type. Such a practice is said to be beneficial in preparing the unbroken muck pasture for its initial crop of Hungarian millet, barley, or oats, after which it is ready for corn.

Distribution of the Muck is spotty and irregular, with a few large contiguous areas in southern Lake County (site of the former "Deep Marsh") in the English Lake district and in the eastern third of the valley.

Among the last lands to be drained, these Muck areas have lost practically every trace of their former herb (wild-rice) cover, and in its place we find an almost complete utilization for any combination of Kankakee crops. Only locally, where inadequate drainage permits rank weeds to choke out the cultivated products, do we find an idle field (I 35, U 30, river section).

Muck is mint ground, and here figures prominently in the reputation which Indiana holds as the first ranking state in mint production. For some reason mint has not yet invaded the large muck section of Lake County, and apparently has not advanced westward beyond the English Lake district. Mint economy fits in well with corn culture, for muck is excellently adapted to both crops.

Muck areas are distinctive not only for their low, level, black fields, but also for an almost complete absence of farmsteads. These average only about one half to the square mile, or about one fifth of the average of the valley, or one fifteenth of the Plainfield. Muck dust is a real nuisance to the farmer's home within as well as without, and so he locates on the edge rather than in the heart of a large muck field. On the other hand, one type of structure is almost uniformly a fixture of the muck–mint landscape — a mint still, which approximates the size of a small two- or three-room house.

Swamp: The Timber Formation. — The Swamp proper follows the Kankakee River for two thirds of the distance from Momence to South Bend. It forms a belt generally less than a mile in width, but attains a maximum of some two or three miles in its middle course in northern Jasper and adjacent counties. In addition, several square

miles of swamp land, mostly cleared, appears along the Yellow River, tributary of the Kankakee. A comparison of the Fundament map (Map 21) with the modern survey shows only slight changes in the former general pattern of timber distribution incident to the reclamation program. The original dominant species composition as reported in the survey notes of Uriah Briggs — "ash, elm, maple, oak, and birch" — has not changed, except locally where popple invades the clearings.

On the other hand, the type of stand or stocking of the timber has changed tremendously. Once including many towering and massive trunks up to three or four feet in diameter, the modern Swamp has only a very sparse sprinkling of maples, elms, and other species of merchantable log quality. The characteristic stand is made up of young timber under three or from three to six inches in diameter, with a sprinkling of timber six to twelve inches in diameter (K 9, N 28, S 5).

Repeated attacks by axe, fire, and fungus have produced a motley patched effect of black fire-charred or disease-ridden trunks mingled with scattered sprouting stumps, thick reproduction stands of single species, the whole interspersed with a brush undergrowth of rank shrubs and weeds. Locally the partly cleared areas are pastured. These take on more of a grove aspect, are relatively free from underbrush, and occasionally form meadows with only here and there clumps of bushes.

Corn is practically the only crop of importance in the Kankakee swamp. Oats and wheat are represented sparingly, chiefly in the Yellow River territory; locally also a truck patch. The soil, of a generally light texture with an admixture of nonhumified wood, seems readily convertible into productive corn land, but because of proximity to the river is mostly subject to overflow during times of high water. Late spring floods may thus unduly postpone the planting season.

Recreation and Conservation

The Swamp represents the last line of retreat for the recreationist. And by the final straightening out of the old meandering Kankakee in Indiana the resorter has lost all but a few remnants of the natural landscape which lends charm to such a river retreat. The name Kankakee itself seems doomed to extinction, since some people now refer to the Miller, Place, Marble, and Williams' ditches instead.

The deeply trenched and highly banked river ditch, a chain or two wide, with its rather rapidly moving current and load of sand, has little to offer in the way of river scenery or sport. Once nationally famous for its natural charm, for fishing and boating, the dredged Kankakee of today seems popular locally only for bathing where the current is not too swift. The effect of river straightening on resort developments is strikingly manifested by contrasted conditions on the two sides of the Illinois–Indiana state line. The Illinois Kankakee above Momence, with its essentially unmodified meandering course, can boast of nearly a score of resort establishments. These include some 275 cottages within the short distance of less than a dozen miles of river front; whereas, on the Indiana side, for a distance of over 85 miles, there are hardly a half-dozen resort groups, which number only some 125 cottages, including the unusually large Bohemian resort of about 80 residences.

The river resorts and recreation centers vary in morphological type, conditions of settlement, and points of attraction. We note the following: the pretentious Bohemian "Sumava Forest Resorts" just mentioned, a type of colony in Newton County with urban characteristics; the "None-Such" camp (A 22) featuring horse racing; the "Garden of Eden Golf Club" (C 13); and the resorts, picnic camp grounds, or dancing pavilions at or near river-bridge sites, such as at Baum's (O 26) and Dunne's (Q 15) and at Shelby (H 33).

Finally, the Kankakee State Game Preserve (Starke–La Porte counties) and the private Cameron duck farm (northeast Newton County) represent, we might say, the salvaged residue of the Kankakee swamp lands and wild life.

SUMMARY AND CONCLUSIONS

The Kankakee region of northern Indiana represents an intermorainal marsh reclaimed sector of the Corn Belt, with a unique historicogeographic setting.

A study of the conditions of the fundament reveals a threefold classification of primary land-surface forms: the herb marsh, the timber swamp, and the uplands consisting in part of sandy "barrens" and dunal oak groves. The uplands made possible the early habitation of the otherwise inhospitable marsh-swamp, a site influence in

modified form still conspicuously noticeable in the present reclaimed Kankakee.

After a treaty by the native Pottawatomie with the Federal Government in 1832, providing for the relinquishment of the territory held by the Indian, the marsh wilderness entered upon a century of progress, paralleling the period of urban development of the neighboring metropolis, Chicago, less than fifty miles from its western extremity.

The drama staged in the Kankakee presents a succession of distinct areal scenes and groups of actors. The general theme, as disclosed by the several regional forms of occupance, features a continuous struggle between two forces — those intent on preserving the wildlife forms of plant and animal for their economic, recreational, and conservational utility, as against the group organized to further the program of reclamation. A network of drainage ditches tributary to the straightened, deepened, and widened Kankakee River attests to the complete dispossession of the former group, except locally along the river ditch.

A regional land-surface and soil survey of the reclaimed Kankakee suggests a fivefold physiographic division based on homogeneity of structural and genetic features. Except for the Swamp, these constitute an otherwise disordered pattern. They include the Plainfield, or farmsteaded "island" and woodlot-pasture formation; the Newton, the Plainfield–Maumee transition; the Maumee, the "cornscape"; Muck, the mint soil; and Swamp, the river-timber formation and resorter's retreat. These constitute approximately 13, 5, 60, 15, and 7 per cent of the area, respectively.

Rural settlement within the area is found to be most remarkably related to the diverse surface and soil influences. Farmsteads average a little less than three per square mile; the proportions of farmhouse distribution for these physiographic divisions approximate 22:1; 9:1; 5:1; 1.5:1; 1:1, respectively. Some four hundred resort cottages are found along the river ditch, mostly along the "natural" Kankakee on the Illinois side.

A sectional grid road system, 55 per cent hard-surfaced, makes for ready internal circulation and external contact with the rim of a score of towns which outline the boundary of the early marsh.

Agitation to restore parts of the once nationally famous "hunter's and fisherman's paradise" raises the questions, "Has the reclamation

program justified itself?" and "Is partial marsh restoration practicable?"

Inventory of soils, crops, and occupance conditions seems to prove the general fitness of the Kankakee for agricultural use. The lands of marginal utility or waste areas are included chiefly in the narrow imperfectly drained Swamp, and the local spots of the droughty sandy Plainfield. Yet it is doubtful whether such a grand haven of wild life would ever again be permitted to be despoiled by man.

Salvaging areas for wild life presents both economic and engineering difficulties. Most promising is the swamp tract of some twelve sections of fire-scarred timber, chiefly in northern Jasper County.

In addition to the possible limited expansion of the swamp conservation and resorting program, we may expect other changes in the future: smaller farms, a larger animal industry, particularly dairying, and increased trucking. On the basis of the predicted unprecedented growth of the metropolitan district to the northwest, the Kankakee trucking areas may yet become "The Garden of Chicago."

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BIBLIOGRAPHY

1. Andrews, R. C., and Andrews, E. Report on Proposed Kankakee River Improvement. (Typewritten copy in Indiana State Library.) 1915.
2. Austin, W. L. Drainage of Agricultural Lands. Fifteenth Census of the United States (1930). U. S. Dept. of Commerce. 1932.
3. Ball, T. H. Northwestern Indiana from 1800 to 1900. Donohue and Hennebery, Chicago, 1900.
4. Biennial Report. Indiana State Commissioner of Fish and Game, pp. 80–84. 1913.
5. Biological Survey, U. S. Dept. of Agric. Report on Suitability for Migratory Bird Refuge Purposes of the Kankakee River Bottoms, Indiana. (Issued as a mimeographed copy.) 1932.
6. Bradley, F. H. Geology of Kankakee and Iroquois Counties. Geology of Illinois, Ill. Geol. Surv., 4: 226–240. 1870.
7. Bushnell, T. M. Physiography of the Kankakee Region. Proc. Ind. Acad. Sci., 37: 141–142. 1927.
8. —— and Barrett, W. Soil Survey of Porter County, Indiana. Bureau of Soils, U. S. Dept. of Agric. Eighteenth Report, pp. 1695–1737. 1916.
9. —— and Others. Soil Survey of Lake County, Indiana. Bureau of Soils, U. S. Dept. of Agric. Nineteenth Report, pp. 1139–1182. 1917.

10. Campbell, J. L. The Kankakee River and Pure Water for Northwestern Indiana and Chicago. Proc. Ind. Acad. Sci., pp. 70–72. 1891.

11. Chamberlin, T. C. Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch. U. S. Geol. Surv., Third Ann. Rep., pp. 291–402. 1881–82.

12. Division of Engineering, State Department of Conservation, Indiana. Report on Ground Water Investigations in the Kankakee Valley. (Unpublished typewritten report based on data collected 1923–27.)

13. Frazier, W. H. Kankakee River Survey to Determine Areas for Restoration. Indiana Department of Conservation. (Typewritten report.) 1934.

14. Grimes, E. J., and Others. Soil Survey of Starke County, Indiana. Bureau of Soils, U. S. Dept. of Agric. Seventeenth Report, pp. 1385–1422. 1917.

15. Hahn, W. L. Mammals of Indiana. Dept. of Geol. and Nat. Res. of Indiana. Thirty-third Annual Report, pp. 417–663. 1908.

16. Hopkins, C. G. Kankakee County, Soils. Agric. Exper. Sta., Univ. of Ill., Urbana. Report No. 13. 1916.

17. House of Representatives, Seventy-first Congress. Doc. No. 784. 1931.

18. Leverett, F. The Illinois Glacial Lobe. U. S. Geol. Surv., Mon. 38: 1–817. 1899.

19. Martin, R. J. Climatic Summary of the United States. Northern Indiana Weather Bureau, U. S. Dept. of Agric. Section 66. 1930.

20. Montgomery, H. T. The Kankakee Valley. Proc. Ind. Acad. Sci., pp. 277–282. 1898.

21. —— The Geological History of St. Joseph County, Indiana. Northern Indiana Historical Society. Publication No. 2. 1929.

22. Neill, N. P., and Tharp, W. E. Soil Survey of Newton County, Indiana. Bureau of Soils, U. S. Dept. of Agric. Seventh Report, pp. 647–779. 1905.

23. Quinn, E. J. Soil Survey of La Porte and St. Joseph Counties. Dept. of Geol. and Nat. Res. of Indiana. Thirty-sixth Annual Report, pp. 281–319. 1911.

24. Reed, E. A. Tales of a Vanishing River. John Lane Co., New York. 1920.

25. Scott, S. L. Has Dredging the Kankakee Basin Overdrained the Principal Soil Types? (A Master's Thesis, Purdue University.) 1928.

26. U. S. Senate Document. Forty-sixth Congress. Doc. No. 107. 1880.

27. Werich, J. Lorenzo. Pioneer Hunters of the Kankakee. Chronical Printing Co., Logansport, Indiana. 1920.

28. Wilson, G. R. Indiana Historical Society, Vol. 6, No. 3. 1919.

29. Young, E. C., and Elliott, F. F. Types of Farming in Indiana. Agric. Exper. Sta., Purdue University. Bull. No. 342. 1930.

A STUDY OF THE POPULATION GROWTH OF NEW YORK STATE

H. THOMPSON STRAW

THE purpose of this paper is to divide New York State into areas according to population growth (see Map 25). In order to do this the population graph of each minor civil division, in this case the town, has been compared with the ideal population graph as constructed by Dodge.[1] Thus, if the town has had a continuous growth of population up to 1930, it is placed in the first class. If decline has occurred, but the population is more than three fourths of the maximum, the town is placed in the class of relatively stable. If the population is between three fourths and one half of the maximum, the town is placed in the class of partial decline. If the decline is more than one half, the town is placed in the class of marked decline.

Probably the most outstanding fact concerning the distribution of the various categories of population growth and decline of New York State is that within a state which has enjoyed a continuous and steady growth from 1790 to 1930, and whose rate of increase has exceeded that of the entire nation, there should be included so much area which has suffered a marked decline in population. This seems still more unusual when the state is considered by county units. Of the sixty-two counties, thirty-three, or more than half, are still increasing in population; only twenty-nine, or 46 per cent, have reached a relatively stable condition; and only two have suffered a decline and that, in each case, has been but partial.

There are in general two major areas of marked decline. Both are in those parts of the state having the greatest relief: the Adirondacks, and the Catskills and the northward extension of the Appalachian Plateau. Both have embedded within them some sections which are still increasing in population. In the Adirondacks these are of a small

[1] For a more detailed explanation of this method see Dodge, Stanley D., "A Study of Population in Vermont and New Hampshire," *Pap. Mich. Acad. Sci., Arts and Letters*, 18 (1932): 131–134. 1933.

density of population and are in general associated with the growth of resort places, a development which has taken place within the past thirty years. In the Catskills and the Appalachian Plateau, however, these sections are located mainly in the southern part, and the north contains most of the towns of marked decline. These subdivisions are somewhat similar in that they both possess relatively high altitudes and rugged relief, but the southern tier of counties includes certain broad rich valleys and has the advantage of an east-west route of travel along the river valleys of the Susquehanna and the Chemung, which is second only to the route through the Great L Valley. Most of the sections of continued growth are associated either with the small market towns of the valleys or, as in the case of the areas about Elmira and Binghamton, with large cities.

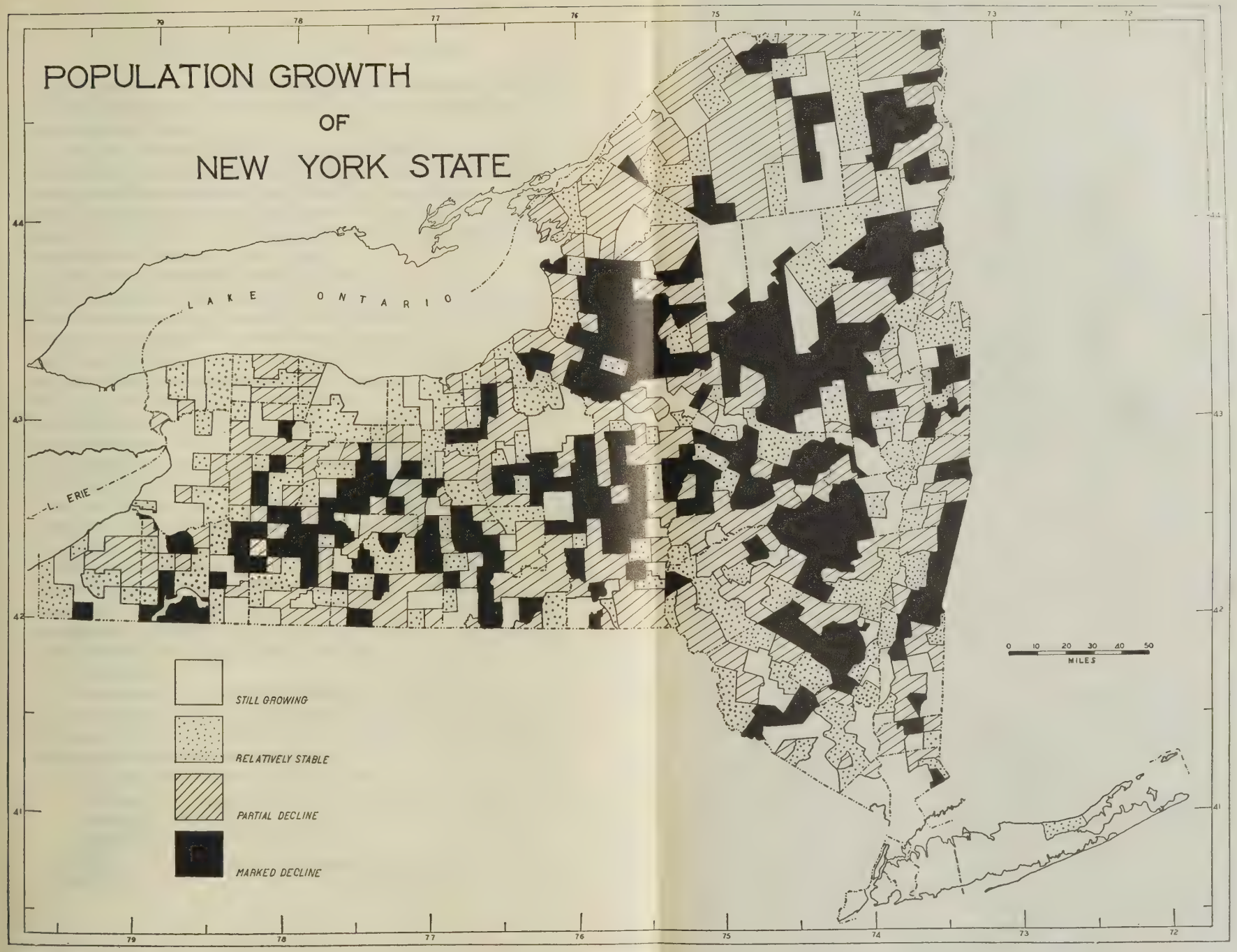
The major distribution of areas which have continued to grow in population, although contiguous, may be divided into three parts. First, there is the area about New York City, including both the larger part of Long Island and that part of the state immediately north and northwest of the city; second, the central portion of the Great L Valley,[2] in which there is an almost continuous line of towns from New York to Buffalo, the population of which is still growing; and third, the area about such lake-port cities as Buffalo and Rochester. In passing, it is of interest to note that these areas of increase represent a little over 10 per cent of that of the state, and as early as 1915 they contained, according to Brigham,[3] 70.87 per cent of the population of the state. Later studies have indicated their continued increase since that time.[4]

A glance at a relief map shows that these areas of population growth are within the lowland portion of the state mainly below the 600-foot contour level. To understand this concentration and continued growth of population, however, it is necessary to understand the social processes which underlie and to some extent explain the present-day distribution. They are the migration from farms to urban centers, which began in New York State about 1880; the urbanization process, which began about 1850; and the suburbanization of

[2] Brigham, A. P., "The Population of New York State," *Geog. Rev.*, 2: 216. 1916.

[3] *Op. cit.*, p. 215.

[4] *Report of the Committee on Housing and Regional Planning to Gov. Alfred E. Smith*, pp. 13, 36. The pertinent part of this report may be consulted more conveniently in Anderson, p. 15, as cited in note 5.


POPULATION GROWTH
OF
NEW YORK STATE
LAKE ONTARIO
L. ERIE
STILL GROWING
RELATIVELY STABLE
PARTIAL DECLINE
MARKED DECLINE
0 10 20 30 40 50
MILES

Map 25

POPULATION GROWTH

OF

NEW YORK STATE

areas adjacent to urban centers, which began around New York City about 1900 and which, within the last few years, has greatly increased in rapidity and extent.[5]

The area of continued growth about New York City is largely due to the suburbanization trend within the past three decades. Cheaper living conditions, especially land prices and rents, coupled with the desire of many people to live in the open country, have motivated the migration.[6] The recent development of hard-surfaced roads has accelerated and extended the movement.

The area of continued growth in central portions of the Great L Valley is associated with the growth of urbanism within the state and has been augmented by the migration of farm population from areas which did not possess large cities [7] and by the suburban development about each urban center. This valley contains the major industrial and transportational enterprises of the state, and at the same time is the region best suited for agriculture.[8] Prior to the limiting of foreign immigration by the United States government the natural increase of population within this area was augmented not only by the interstate migration of farm population, but by the addition of the foreign-born as well.[9] The suburban development here, as near New York City also, has its effect. Although it started at a somewhat later date, it has already been responsible for much of the increase about the larger urban units.

The area of continued growth about the lake-port cities scarcely needs explanation. Here is urbanization mainly dependent upon the demand for transportation and in some cases augmented by industrial development. Like the cities of the Great L Valley these ports have also attracted their share of the farm population and of the immigrated foreigners.

The areas of relative stability and partial decline occupy most of the remainder of the map. Their general location seems to be between the areas of marked decline and those of continued growth. They appear to be areas of transition.

This completes the major distributions shown upon the map.

[5] Anderson, W. A., *Population Trends in New York State, 1900 to 1930*, pp. 6–7.
[6] Anderson, *op. cit.*, p. 26.
[7] Page 15 of the *Report* cited in note 4.
[8] Anderson, *op. cit.*, p. 15.
[9] Anderson, W. A., *Movement of Population to and from New York State*, p. 9, fig. 1.

There are numerous small "islands" which do not seem to fit into the surrounding areas. In some cases these differences may be due, as has been suggested by Dodge,[10] to the fact that the unit of the town is too large. In other cases some obscure local difference, which only field work could uncover, may be responsible. Many of these small local exceptions, however, are due to the fact that no rigid categories, no matter how wisely conceived, can always fit the delicate gradations of reality.

University of Michigan

[10] *Op. cit.*, p. 135.

THE INDUSTRIAL GEOGRAPHY OF THE MIDDLE MIAMI VALLEY, OHIO

ALFRED J. WRIGHT

TOPICAL OUTLINE

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THE Miami Valley of Ohio has afforded for two races the principal corridor between the Ohio Valley and Lake Erie (Map 26). Since the late eighteenth century this valley in southwestern Ohio has been occupied by white settlements, which, for rapidity of growth and density of distribution, have been exceeded by few areas in the old Northwest Territory. An Indian agricultural and trading region, a frontier community whose agricultural surplus early led to commerce and manufacturing, and an industrial region whose development has been characterized by variety and high manufacturing value — each of these has in turn profited from the river location, and to a marked degree they all have had their origin rooted in these facts of situation.

The present valley is a highly industrialized region in which the

Map 26. Situation of the Miami Valley (hatched) with respect to the principal routes through the Appalachian barrier followed by early Ohio settlers (after Fenneman)

fundamental location facts now find expression in the nature and extent of its manufacturing. It derives additional significance from having become a strongly individualized region in the process of its utilization.

APPROPRIATIVE PERIOD

Earliest of the known occupants of the Miami Valley were the so-called Mound Builders, who took their name from the most obvious difference from their Indian successors. Their earthworks are found in sufficient number and variety to warrant the conclusion that these people were resident in the Miami Valley through several generations of culture and that their economy was primarily agricultural.[1]

INDIAN

As resident Indian country with an established agricultural economy, the Miami Valley seems also to have been an important

[1] Mills, W. C., *Archaeological Atlas of Ohio* (Columbus, 1914), Plate XI and text.

corridor for the Miamis and the Tawichtawis who occupied the middle and upper valley at the time of earliest white penetration.[2]

The climax of Indian occupancy occurred during the relatively brief period of struggle with the westward-moving whites. The number and the ferocity of the engagements between the two races for the possession of the valley gave rise to its popular name "Miami Slaughter House." This name testifies to the essential fact of its high appraisal by both races, as well as to the manner in which the change in culture was effected.

TARDY WHITE APPROPRIATION

During the first quarter of the eighteenth century fur traders from the French post at Detroit and English traders from the seaboard colonies were initiating the profitable fur trade with the Indians of the Miami country. In addition, the French regarded the valley as the right-of-way to their colonies in Louisiana. To the British this valley was the principal route from their tidewater colonies to the last stronghold of the French at Detroit. Thus it became a matter of policy for the two nations to preserve the valley for the exclusive use of the Indians they sought to make their allies. The safeguarding of it became at once a source of strength and a major weakness in the policies of occupation and appropriation of the two peoples.

Even after the Ordinance of 1787 provided for the government of the Northwest Territory, the final stage in the appropriation and development of the region was delayed by the reluctance of the youthful Federal Government to supervise and police this first unit of the public domain.[3]

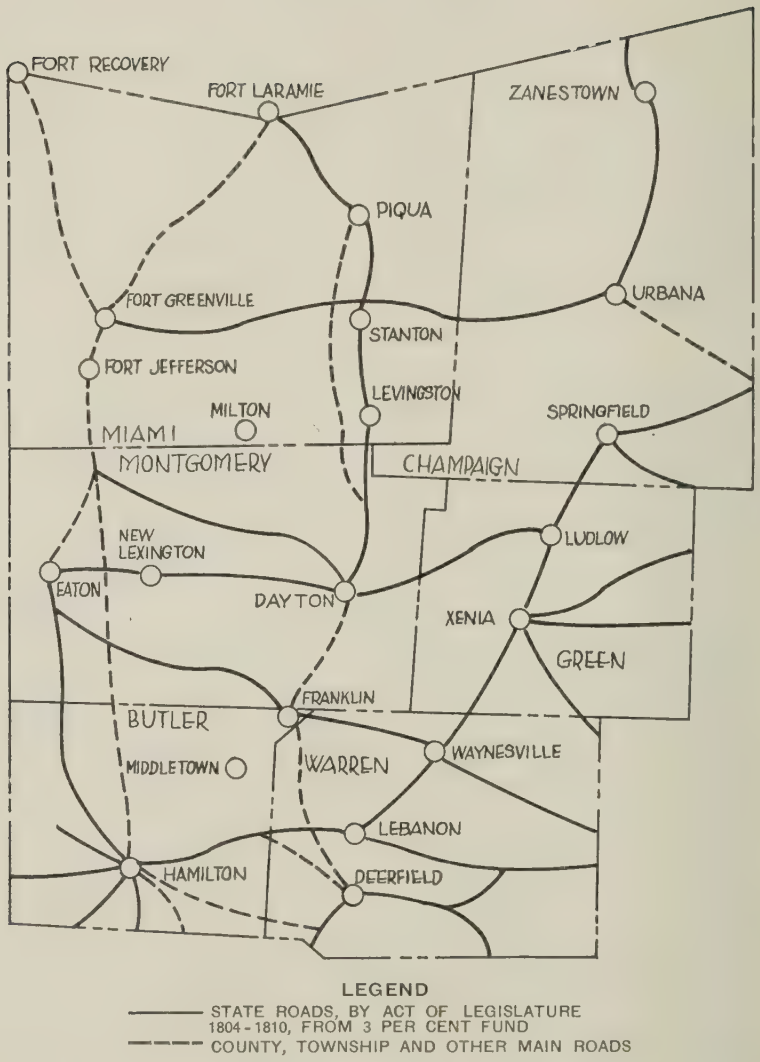
RIVER AND CANAL PERIOD

POPULATION

Between the date of the valley's first white settlement in 1788 and the preparation of the first map by the state in 1810 settlement

[2] Hulbert, A. B., *Red Men's Roads*, Ohio Historical Society Publication (Columbus, 1900), pp. 5–37; Mills, *op. cit.*, Plate IX; Filson, John, map of Kentucky, 1784, republished by the Loudermilk Company, Washington, 1908; Putnam, Rufus, map of Ohio, 1804, in *A Journal of a Tour into the Territory Northwest of the Allegheny Mountains*, by T. M. Harris (Boston, 1805).

[3] Goodwin, F. P., "Growth of Ohio," *University of Cincinnati Studies*, Series II, 4: 51–53. 1906; Thwaites, R., *The Colonies* (New York, 1902), pp. 151, 165.



MAP 27. Towns and roads of the middle valley in 1810. The northern boundary (Greenville Treaty Line) abruptly halted all settlement. Data are from a manuscript map in the Sir Henry Clinton Papers, Clements Library, Ann Arbor, Michigan, and from the *Ohio State Survey of Transportation* (Columbus, Ohio, 1925). Scale: 1 inch = 15 miles

had spread from the Ohio River northward to the Greenville Treaty Line, eastward from the Miami to the closed lands of the Virginia Military District, and westward to the Indian territory just beyond the state boundary. The estimated 70,000 people were found in three major lines of settlement, each following a principal stream.[4] The larger towns were along the Miami River, centering about Dayton and Hamilton. The Little Miami and the Mad River valleys were in effect one line of settlement, with Springfield as the major agglomeration. The third and least populous grouping was along the Stillwater, the principal western tributary of the Miami (Map 27).

Such town and village names as Wilmington, Waynesville, Washington Court House, Greenville, Jamestown, and Alexandria have their prototypes in the Old South; Trenton, Germantown, Camden, Springfield, Rochester, Ithaca, Utica, Gettysburg, Westchester, and Pemberton have theirs principally in southeastern Pennsylvania and west-central New Jersey. In general, it may be said that the southern states made their chief contribution during the earlier years of the Miami Valley, while the middle Atlantic states were represented more heavily in later years.[5]

CIRCULATION

Although the Miami River was noted on some early maps as navigable, it was used principally during periods of high water by flatboats and a few keel boats as far north as Dayton. Since there was no local market for the valley's agricultural surplus, flatboating to New Orleans was a vital necessity until the Miami and Dayton Canal was opened in 1829. Such commerce was imperative on account of the current practice of Dayton merchants of accepting in payment for sales wheat, corn, pork, and liquor, "if delivered in time for the next freshet," or any commodity "easily transported on horseback, such as beeswax, liquor, and woollen cloth." [6] Goods, services, and real estate were sold in this manner for two decades or more in the middle Miami Valley, and for a longer period in less accessible

[4] Drake, Dr. Daniel, *A Natural and Statistical View of Cincinnati and the Miami Country in 1815* (Looker and Wallace Company, Cincinnati, 1815), p. 169.

[5] Bond, B. W., Jr., *The Correspondence of John Cleves Symmes* (Macmillan Company, New York, 1926), pp. 42, 282–287; Morrow, Josiah, historian, Lebanon, Ohio, letter dated January 26, 1928.

[6] Steele, R. W., *Early Dayton* (Dayton, 1916), pp. 103–106; Howe, Henry, *Historical Collections of Ohio* (Columbus, 1886), pp. 277–278.

parts of the state. Even during the winter months Dayton's water front and forwarding warehouses were busy with storing and loading nonperishable commodities, in which wheat was increasingly important.[7]

Military appraisal of the trails of this region and their subsequent use by the military constitute the pioneer stage of Miami Valley roads, and the close of the War of 1812 may be said to have marked the end of the first period of road building.[8]

Prior to 1787 the expeditions against the Indians were largely punitive in nature, but after the passage of the Ordinance of the Northwest Territory detachments of the United States regular army developed, over a period of thirty-five years, a road system which served throughout the year, not only for the campaigns but also for the struggling settlements of the Miami Country.

The character of these roads changed with the demand of the times; narrow trails unfit for wheeled vehicles but used by long-line teams of a dozen horses or more, the freight wagon, and its companion, the stagecoach, ushered in the first Federal aid in road building.

MIAMI VALLEY INDUSTRIES

The entire middle Valley was described in 1816 as having "invited that hardy and numerous body of free-holders that inhabit it to select themselves moderate and nearly equalized farms and to dot and intersperse them over its surface. In regard to the smallness of the farms, the number and quality of them, the compactness of the population, — not confined, as is the case farther west, to the watercourses, — but diffused over the whole region, it compares very accurately with its eastern parent. At present the regions on Mad River and the middle Miami Valley are the most beauteous and populous in the State. It is the only 'Yankee State' west of the mountains." [9]

During the period of appropriation obstacles were met in clearing

[7] Drake, *op. cit.*, pp. 50–55; *Liberty Hall*, Cincinnati, issue of August 4, 1806.

[8] Melish, John, *Travels through the United States in 1806, 7, 8, 9, 10, 11* (published in Ireland), pp. 27–90; Gephart, W. F., "Transportation and Industrial Development in the Middle West," *Studies in History, Economics and Public Law* (Columbia University, 1909), 34: 19–50.

[9] Flint, Timothy, *Recollections of the Past Ten Years, a Series of Letters to Rev. Jas. Flint, of Salem, Mass.* (Cummings, Hillard and Company, Boston, 1826), pp. 44–54.

the splendid hardwood forest, disposing of the agricultural surplus, and finding an outlet for the perishable products. The solution of these problems gave rise to industries, some of which were transient in nature, but many of which have persisted. Low prices prevailing locally for farm products led to the driving of stock cattle, bullocks, and swine from the corn and grasslands of the Miami Valley to Atlantic seaboard markets. These droves, numbering from a thousand to fifteen hundred head, usually followed the old Cumberland Road eastward from Springfield to Baltimore. In the early 1850's the accelerated packing in Cincinnati put an end to droving.[10]

Variety marked the exports and imports as changes in the domestic economy took place, in keeping with the advancing occupation of the region. In 1799 there were reported in Dayton a distillery, a sawmill, a lime plant, and a corn cracker; by 1804 a grist mill was in operation; in 1808 a nail factory was using charcoal brought by water from the Hanging Rock iron furnaces of southeastern Ohio. In 1824 a cotton mill was put into operation, with fiber brought by water from the South. In 1828, the year before the Miami and Dayton Canal was opened, the first iron foundry was established there. In that year Dayton's industries were listed as three tanyards, three saddler shops, one flour mill with three "run" of stone, a fulling mill, one set of carding machines, a cotton mill, two distilleries, a coppersmith shop, a tin shop, a carriage shop, three wagonmakers' establishments, four blacksmith shops, two printing shops, and one wholesale warehouse, as well as taverns, groceries, and dry-goods stores.[11]

Elsewhere in the Miami Valley industrial development was consonant with that of Dayton. The Census of 1820 shows that slightly more than half of the 2,000,000 barrels of flour milled in Ohio were the product of Miami Valley mills. Exporting mills were along the Miami and Mad rivers only, but there were scores of small mills along the minor streams of the valley.

FACTORS HINDERING MANUFACTURING

Despite the necessity of satisfying the local market and the demands of the southern states for many staples, manufacturing in

[10] King, I. F., "Coming and Going of Ohio Droving," *Ohio Historical Society Publication*, 17: 240–250; *Ohio Agricultural Experiment Station, Bulletin 326* (1918), pp. 240–243; Cist, C., *Cincinnati in 1851* (Cincinnati, 1852), pp. 278–288.

[11] From a letter quoted by Steele, *op. cit.*, pp. 149–150.

the valley during the river period was retarded by lack of capital and labor. An abundance of fertile land could be had for approximately a dollar an acre. The population of the region grew slowly for the first fifteen years of occupance, and even later the towns decreased in size with the advent of early summer, while new farms were laid out in the unoccupied part of the valley. Despite the very low prices for farm products the attraction of the Miami Valley farm was greater than that of the manufacturing plant.[12]

Few of the people were skilled in manufacturing, simple though the fabrication was. About them there was no coal, iron, or other industrial mineral. Transportation was by water, and the rivers were seasonal in service. The outlet was toward the south only, and such manufactured goods as the South demanded were imported from Europe and paid for with raw cotton. Even among an increasing rural population purchasing power developed slowly because of the low prices received for domestic goods and the high prices for imports.

FACTORS FAVORING MANUFACTURING

The outstanding difference between the factors which retarded and those which encouraged manufacturing in the valley was that the former, as a class, tended to be temporary in nature, whereas many of the latter have steadily appreciated in importance.

The agricultural surplus needed only the inevitable increased market and improved transportation to become the principal demand factor for the development of manufacturing. The market increased during the years after 1815 and, with the opening of the canal in 1829, the transportation factor was somewhat less a handicap to industrial growth. During the river period the most widespread phase of manufacturing was distilling. Every village had a commercial distillery, and nearly every farm had its own small still. To the valley farmer of that day the still was almost as important as the grain elevator is now. Corn, rye, barley, and some apples, cherries, peaches, plums, berries, and pears were thus barreled for local consumption and shipment to the south. Liquor suffered the minimum depreciation as a medium of exchange.[13]

[12] Bond, *op. cit.*, pp. 126–130; Drake, *op. cit.*, pp. 38–50.
[13] Howe, *op. cit.*, 2 : 275–278.

OPENING OF THE CANAL

The opening of the Miami and Dayton Canal in 1829 and the ultimate extensions to make it the Miami and Erie Canal, resulted in one major change in the cultural landscape: the canal counties and their valley cities experienced an acceleration in growth greater than that of other counties in the Miami basin. It followed an established trade route, and no new agglomerations rose to mark its influence. In 1850 the thirty-seven canal counties in Ohio exceeded in assessed property valuation the fifty-one noncanal counties by more than $88,000,000. Six of these canal counties were in the Miami Valley. Of the twenty-two largest cities in the state fourteen were on the canals, four on the Lake, and four on the Ohio River.

In addition to the growth of the largest cities the canal brought such fundamental changes in the local economy as to cause smaller places to share in the acceleration of settlement. Middletown, Franklin, Miamisburg, West Carrollton, Troy, Piqua, and Sidney became important forwarding centers, drawing upon the countryside for exportable raw materials and catering to the market of their respective trading centers for manufactured and imported goods.

The peak of canal tolls and of the canal's influence was in 1851, but, though little was done to stimulate shipments, the Miami and Erie clung to activity most tenaciously of all Ohio canals. In 1897 its receipts were almost as great as in 1843, and even greater than during the early years of the railroad, 1860–80.

The economy of the middle valley farms may be appraised from their commerce as noted in the *Annual Reports of the Board of Public Works for 1852*, page 24.

TABLE I

COMMERCE OF CINCINNATI IN 1850 AND 1851

Commodity	Tonnage 1850		Tonnage 1851	
	Arrived	Cleared	Arrived	Cleared
Flour and wheat	14,273	551	27,840	181
Corn	17,332	.....	7,560	.....
Pork, bacon, and lard	7,782	3,303	4,282	4,415
Iron	498	3,061	2,590	4,415
Merchandise	3,422	2,727	2,791	3,161
Paper	449	29	815	55
Cotton and yarn	110	274	80	363

RAILROAD PERIOD

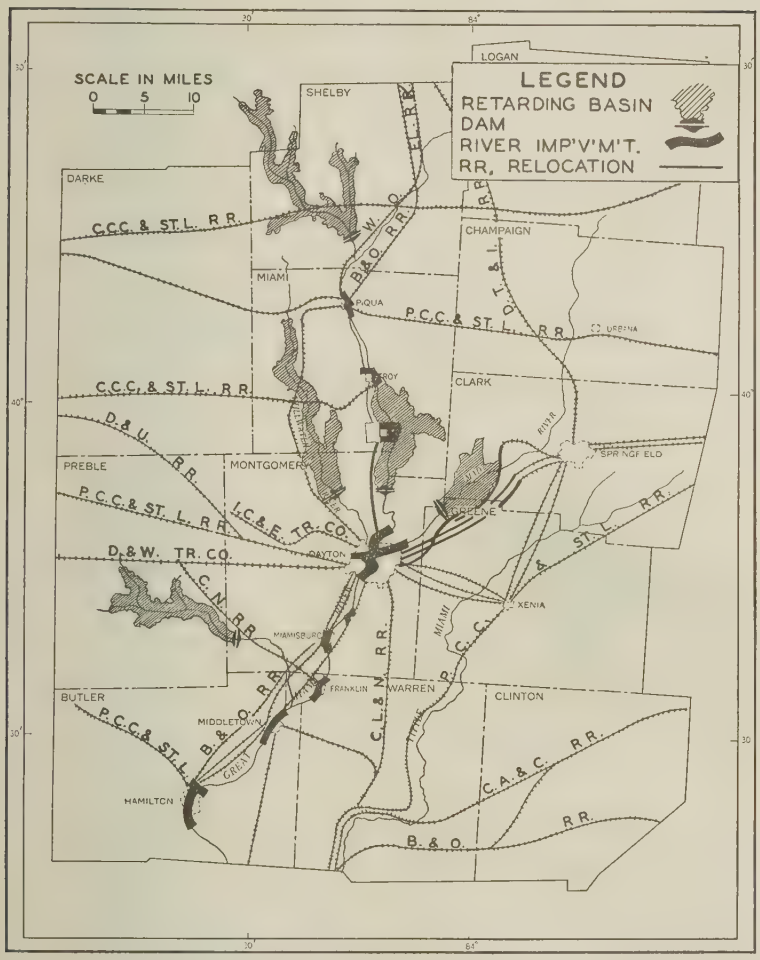
Though in general the first railroads seem to have been built with the idea of reaching the parts of the country not served by the rivers and canals, those in the Miami Valley were exceptions. They found the route of the Miami and Erie Canal a region of cities and towns with established markets; competition between canal and railroad first began here, so far as the trans-Appalachian west is concerned. In 1848 the valley cities were served by three lines, connecting with Toledo in the north, Cleveland in the northeast, and Marietta in the southeast.[14]

The effect of railroads upon the population pattern of the middle Miami Valley was manifested, generally, in three ways: (1) A small agglomeration might grow about the depot, embracing the stock-loading pens, grain elevator, sawmill and lumber yard, warehouses for wool and tobacco, and perhaps a canning plant for corn or other vegetables. This group functioned integrally, with its village situated at a distance of from one-half to two miles from the railroad. In certain instances the intervening gap was built up, and the two units became physically and economically one. (2) Another manifestation was the development of a village nucleus about the depot, which seldom numbered more than half a dozen structures, yet which existed independently of any other village or town. (3) The most important result of rail transportation was instanced in all the major agglomerations of the middle valley. They were divorced from their river and canal attachment to become, instead, dependent upon the railroad (Maps 28–30).

The pattern and character of the railroads may be observed in the focusing of interregional north south and east west lines upon the middle valley (Map 28). Despite the low relief of the region railroads tend to follow the major valleys in serving southwestern Ohio, a fact occasioned by the strictly riparian location of cities antedating both canal and rail transportation.

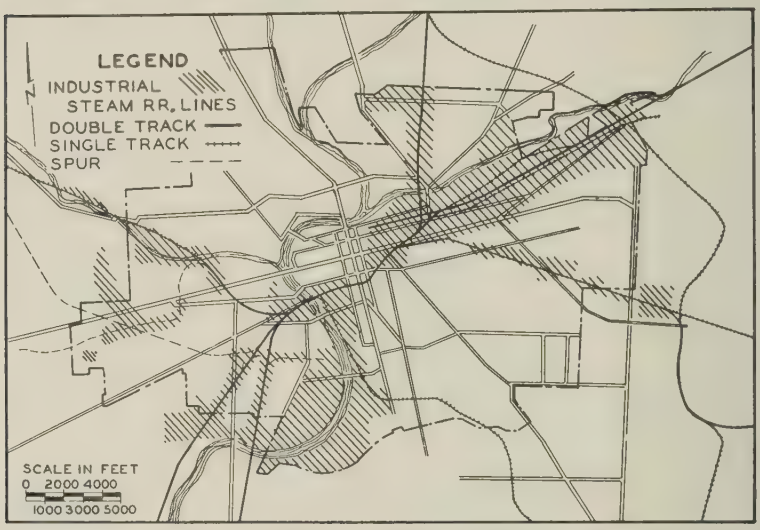
Nomenclature of the lines serving the valley is indicative of their special relationship to focal points in the railroad network of the Ohio Valley and more remote regions. Of these the Pittsburgh, Cincinnati, Chicago, and St. Louis Railroad marks the great trade track

[14] *First Annual Report, Ohio Commission of Railroads and Telegraph*, 1867 (cover insert map).



Map 28. Correlation of the Miami Valley railroads with the Conservancy District Works. For clarity the location of railroads in congested districts has been approximated. Data are from *Ohio Railroads* (published by the State, 1925), and *Bulletin of the Miami Conservancy District, Dayton* (1918)

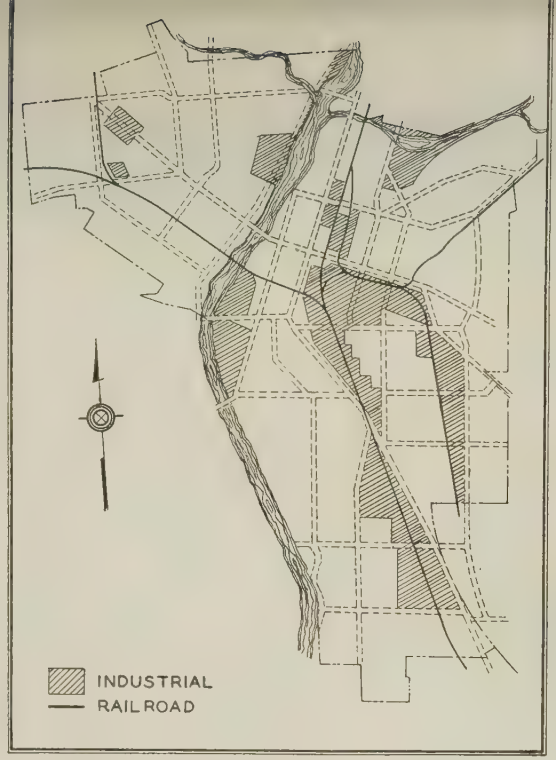
comprehending these commercial nuclei. The St. Louis and Indianapolis divisions of this road are direct rail connections with southeastern Pennsylvania and the port of Philadelphia. The Baltimore and Ohio Railroad marks the oldest direct route to the Atlantic seaboard. Together, these two lines indicate the focusing effect of the Appalachian barrier upon commerce. The Cleveland, Cincinnati, Chicago, and St. Louis Railroad, or the Big Four, likewise reflects this force. The Erie Railroad completes the regional network of through lines.



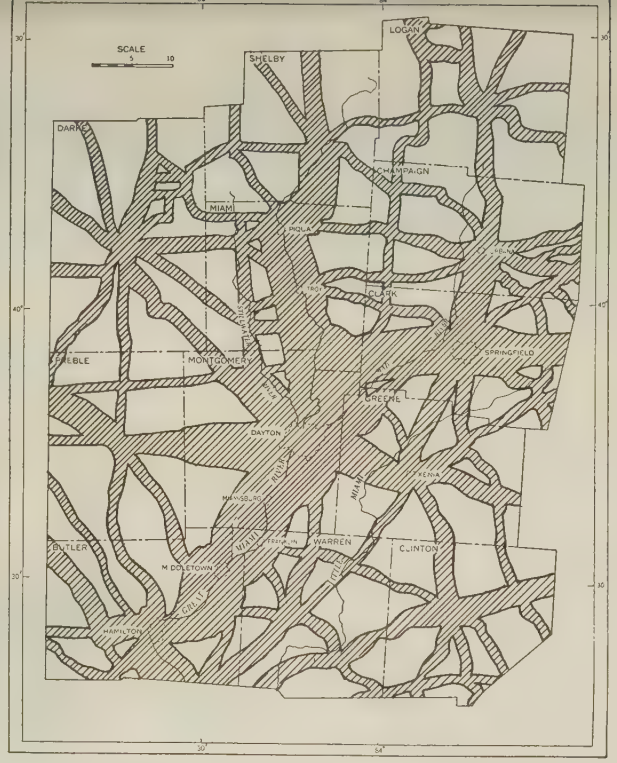
Map 29. Dayton's industrial areas are characterized by their relative permanency of pattern and by their attachment to surrounding medium-residential neighborhood

An intraregional line is the Cincinnati, Lebanon, and Northern, which serves the lower and middle valley, with a right-of-way whose principal advantage is its elevation above flood waters.

The paucity of fragmentary lines constructed in the Miami Valley is indicative of the economy of the region as well as of its spatial relation with the rail net of the Ohio Valley. Of the factors which might give rise to such roads quarrying and the transfer of molten iron from Hamilton to Middletown are the only examples in the middle valley.



MAP 30



MAP 31

MAP 30. Hamilton's industrial areas, which clearly reflect the localizing effect of the railroad. As in Dayton, the great majority of manufacturing plants are integral parts of the city proper. Scale: 1 inch = 5,000 feet

MAP 31. The motor-traffic pattern manifests the crossing of major routes of trade. Scale: one inch is the equivalent of 1,000 vehicles daily. Data are from *Ohio State Survey of Transportation* (Columbus, Ohio, 1925)

CHANGES IN RAILROAD PATTERN

Changes in these railroads have been few and have affected the population but slightly. As in other parts of the midwest, most electric lines have been torn up since the World War. There is but one left in this region; it connects the Ohio River with Lake Erie by way of Cincinnati, Dayton, and Springfield.

Probably the most significant change in the rail net has been that associated with the flood-control program of the Miami Valley, completed in 1918. It embraced relocation of railroads, widened stream channels, fewer confining bridges, and substitution of a different type of riparian occupancy for the congested and encroaching type of an earlier day (Map 28). In a sense these riparian changes in land use may be regarded as a measure of the declining importance of riparian industrial sites.

INDUSTRIAL STRUCTURE

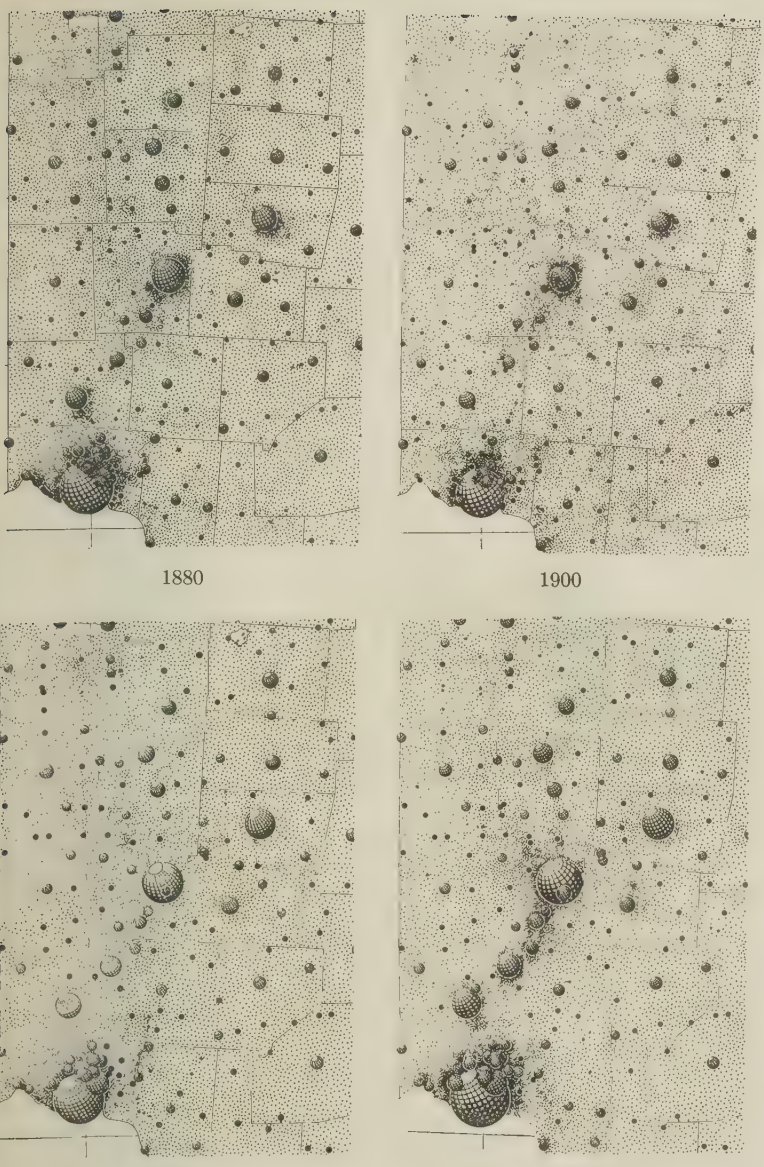
Increments of growth are still due to the forces governing the early growth of the valley: uprooting forces emanating principally from Cincinnati and Dayton; attractive forces where the valley has been crossed by, or has absorbed, major east–west trade routes; and, finally, the intensified agricultural use of the area (Map 31). Thus with respect to population pattern the Miami Valley has undergone no essential modification (Map 32).

The industrial selection which has prevailed since the opening of the canal in 1829 has resulted in a minimum of dispersal of manufacturing, and that is practically confined to the river plain.

Not so persistent, however, has been the essential structure of the valley's industries, although, in general, they developed from those of a century before: food products, machine-shop and foundry products, woollen textiles, and paper.

More detailed examination reveals certain qualities of manufacturing not to be associated with the formative stage of the industrial structure. Specialization within the machinery field has emphasized environmental differences quite as definitely as a change in the class of products. Functional change is manifested by the increasingly high value added by the manufacturing process.[15]

[15] See Thompson, Tracy E., *Materials Used in Manufactures* (Bureau of the Census, Washington, 1929), p. 14.



Map 32. Population of the Miami Valley in 1880, 1900, 1920, and 1930. (Courtesy of Dr. Guy-Harold Smith)

Each of the smallest dots represents twenty-five rural inhabitants localized by civil townships

The fact that without minerals and power the valley has been able to utilize the changing sources of raw materials and of markets is in itself a commentary upon its situation. As concomitants there have been the industrial forces, wholly apart from raw materials, which have developed within the region.

In the analysis of industrial forces operating areally Weber sought to "agglomerate" and "deglomerate" industries within their general regional distribution.[16] Subsequently Colby refined the concept of these forces in the examination of the geographic attachment of lesser to major units in a given region.[17] The application of this discipline in an appraisal of this region's industrial structure is followed, despite the decentralized nature of its manufacturing areas.

UPROOTING FORCES IN PERIPHERY

Centrifugal or uprooting forces have been obvious in the scores of small towns and villages which characterize this densely settled till plain. Their industries were seldom of more than local importance, but in view of their industrial transformation consideration of a typical one is given.

Waynesville, a small town of 700, exemplifies the results of more than a century of industrial selection through which these towns have passed as peripheral to the major urban agglomerations (Map 27). During the pioneer period this village was primarily engaged in processing the ubiquitous raw materials for the satisfaction of the local market: lumber, flour, leather, and whiskey.

The middle of the nineteenth century witnessed the expansion of the village away from the river. Changing values assignable to environmental factors were faithfully reflected in the changed configuration of the village on its site, as well as in the extent and the variety of its manufacturing.

With the construction of highways and the use of steam power the expansion of the village was on the upland. Its main street became a part of a principal artery between Cleveland and Cincinnati; its major cross street was the southernmost highway between the Miami

[16] Artman, C. E., *Industrial Structure of New England* (Dept. of Commerce, Washington, 1930), p. 150; Weber, Alfred, *Theory of the Location of Industries* (Chicago, 1929), Chapter 5.

[17] Colby, C. C., "Centrifugal and Centripetal Forces in Urban Geography," *Ann. Assn. Am. Geog.*, 23: 1–8. 1933.

Valley and the Virginia Military District. The first railroad in Ohio, now part of the Pennsylvania Lines, followed the Little Miami River valley northward to Columbus and Lake Erie. Where this railroad crossed the east–west highway was formed the nucleus for Waynesville station, embracing the depot, stock-loading pens, grain elevator, sawmill, lumber yard, canning plant, and the warehouses for wool and tobacco — an agglomeration functioning integrally with the village but removed from it by the flood plain of the river. This period was characterized by fairly rapid growth of the village and the changed economic horizons resulting from the railroad and improved highway transportation.

The third stage of occupancy is characterized by the economic results of accessibility to other parts of the Miami Valley. This is reflected in the closing of the mills, virtual cessation of local service by the railroad, and, finally, the crystallization of the economic life of the Waynesville region into its present stage of commutation.

A new system of highways came into being, made necessary by the changed and vastly increased commerce within the corn belt (Map 31). The greatest effect, naturally, would be noted not in the immediate marketing of farm products, but rather in regional commerce adapting itself to the new and rapidly growing manufacturing cities of the Miami Valley. When the automobile had demonstrated its superiority in handling certain types of traffic and the railroads had accordingly altered their service program, Waynesville found itself without the rail service to which it had become accustomed and upon which an element of its economy was dependent. Whereas 60 per cent of the farm income of Warren County (Waynesville) is from livestock, divided almost equally between swine and cattle, the stock-loading pens are no longer used.[18]

Although a constant part of the farm income is from tobacco, 19 per cent, the warehouse is not used. Wheat still constitutes some 12 per cent of farm income, but the two flour mills are closed and the elevator handles only a part of the local crop. Receipts from dairy cattle are greater, yet the milk car is no longer a daily part of the morning train. Only one train each way stops at Waynesville, but the number of trains passing through is as great as ever. The agent's time is now divided between two depots within commuting distance.

[18] Data from individual *Farm Schedules* (Bureau of the Census, Department of Commerce, Washington, 1928).

Only the coal yard, the corn-canning plant, the lumber yard, which distributes but does not manufacture, and the elevator remain in operation at Waynesville station.

In the village itself the creamery is closed; trucks swiftly gather up the separated cream for the larger creameries of Dayton and Cincinnati. The two flour mills have closed. The electric light and pumping station is now a unit in a large utilities concern which supplies two score of towns in the valley. Two of the three slaughterhouses are closed; dealers truck their supplies from Dayton and Cincinnati. Wool and tobacco are bought up by buyers from distant warehouses.

With these possibilities for employment closed the number of wage earners commuting to Dayton, Middletown, and Hamilton has steadily increased. On a twenty-mile drive one may see factories in which many types of labor are employed. Outstanding among them are the General Motors and the National Cash Register plants at Dayton, the Niles Tool Works at Hamilton, the American Rolling Mill plants at Middletown and Hamilton, the rag-paper mills scattered from Hamilton to Dayton, and the tobacco factories of Middletown and Dayton. There is represented here a wide variety of wage jobs, with the manufacture of precision machinery predominating. An examination of commutation reveals a definite type of wage earner engaging in it, a type of worker which the great tool plants and manufacturers of automatic and calculating machinery hold at a premium. There is, then, the coincidence of this demand being satisfied by the workers from a valley in which the small proportion of foreign-born are superior types from northwest Europe, and the slowly declining farming population has been absorbed in the ranks of factory workers.

Like many other towns in the valley, Waynesville has a diminishing proportion of retired farmers among its citizenry, yet its population is slowly but steadily increasing. The Census of 1930 shows that, during the decade immediately preceding, these middle valley counties grew more rapidly in population than did the state as a whole — 17 per cent as against 15 per cent. A more definite conception of the nature of this increase on the part of Warren County may be gained by noting the increase in the number of families over a like period; in this particular Warren County gained more than any other county in the valley.

Through commuting Waynesville and scores of villages and towns are crystallizing their economic activities into a mature stage of economic regionalism in which local industrial relicts stand as mute evidence of former areal limitations imposed upon them. The sequent occupancy of this village is complete with the stage which witnesses its integration with the economic life of larger centers whose major activities are geared to the remote as well as to the immediate environment.

OTHER UPROOTING FORCES

Prominent among the centrifugal forces operating within the larger groups comprising the industrial organism of the middle valley is the spatial force. For example, a large manufacturer of safes and vaults moved from Cincinnati to Hamilton because vertical expansion was impossible and horizontal expansion was prohibited by the land values of a large city; American Rolling Mills likewise illustrates this force in operation in the same region. Other industries are King Powder Company and Peters Cartridge Company, whose decentralized manufacturing operations were quite inconsistent with an urban location.

Uprooting forces are to be observed as a result of the program initiated and developed by the Miami Conservancy District. The widened channel precluded continuance of many riparian industrial sites in each river city where their encroachment had jeopardized life and property, either directly or as an obstacle to complete riparian control by the commission. The removal of railroad tracks in turn affected the location of manufacturing plants. The razing of many low-grade buildings, the parking of much of the river bank, the creation of impounded areas, and the construction of new and larger bridges combined to bring about new uses for this land. In Dayton, especially, civic buildings and fraternal and public assembly halls exemplify the new type of riparian land use.

CENTRIPETAL FORCES

Whereas the smaller towns of the periphery reflect an obvious maturing of economic regionalism in the form of local industrial relicts, forces of attraction have also been operative, especially in the larger agglomerations.

Locally the force of functional convenience is manifested in the

agricultural attachments of Miami Valley manufacturing. Flour milling is the most widespread phase of this attachment, although wheat normally accounts for but 12 or 15 per cent of the farm income of these counties.

Most flour mills of the middle valley date from the early railroad period. Although few of them now employ water for power purposes exclusively, many use it as supplementary power. Their wheat has been locally grown, and the flour and feed have been locally consumed. This industry is unique in that so many small units of production have survived the long period of industrial selection. Uprooting forces have been operative, however; among them have been the decline in home baking and the increase in commercial baking; thus each mill caters principally to local consumers. Improved roads and the automobile have made the farmer less dependent upon the nearest elevator. Another uprooting force has been the failure of younger men to take up the work of the older school of millers as they give up active work. The partial failure of local wheat crops in 1926, 1927, and 1928 served to eliminate some marginal mills. As machine replacement became necessary, many of these mills closed or turned to other work.

Thus have the local attachments for flour milling weakened; it has been estimated that a fourth of all mills have closed since the War.[19]

One of the most highly localized of valley industries is the manufacture of tobacco, principally at Middletown and Dayton. Its initiation as a local industry was partly in response to the localization of the state's leaf production in the western and southern tiers of valley counties. Despite the fact that the chewing and smoking tobaccos are largely made of blended tobaccos, early start and cheap labor have combined to retain the industry. The canning of sweet corn, peas, and tomatoes is an important phase of the agricultural industry. Sweet corn, grown under contract, is especially fitted to occupy a place in the crop system of those counties that suffer from yearly inundation by the streams of the Miami basin. Most of these local canneries offer part-time employment to older men and women from the farms and villages; their season is short, three to four weeks in late summer, for in spite of the favorable rainfall régime high temperatures usually militate against a prolonged canning period.

[19] Easterling, T. E., unpublished dissertation on Ohio flour milling, Ohio State University, 1930.

The corn–wheat–livestock phase of the valley's farm economy was not the only one of importance. Between 1840 and 1870 Ohio led the nation in wool production, but today there is no more than in 1840; the decrease is well over 50 per cent.[20]

Paralleling this decline in wool production is a series of technical changes which conditioned its manufacture. Prior to 1880 woollen fabrics of the finest quality were made from yarns spun from the short fibers of the best local fleeces.[21] Although in 1890 there were sixty-four mills in the state producing a variety of products, in 1930 there were but twenty of them remaining in operation.[22]

Typical of the numerous small woollen mills found in the Valley was the one at Springboro, which closed in 1894 after a run of more than three quarters of a century. It employed nine men; within a radius of twenty miles it sold blankets, flannel, stocking yarn, cassimere cloth, and satinette or cloth with a cotton chain.

Although the new fabrics called for a mixture of cotton and wool, or all cotton, the equipment of these early mills would not permit the change. By 1900 all woollen mills in the Miami Valley had closed, except those at Hamilton, Dayton, and Piqua.

The manufacture of cordage and twine at Xenia and Miamisburg utilized local hemp in making cordage for this densely populated agricultural region. Despite the gradual change to tropical fibers imported from Mexico and the Philippines these ropewalks have found that the local agricultural market, supplemented by manufacturing and wholesaling industries, compensates for the uprooting force.

Regional Functional Convenience

Regional functional convenience is expressed by the establishment of branch manufacturing assembly plants by such national concerns as Ford and General Motors at Hamilton and Dayton, International Harvester at Springfield, Niles, Bement, Pond machine tools at Hamilton, Procter and Gamble soap at Dayton, Loose-Wiles baked goods at Dayton, P. Lorillard tobacco at Middletown, Coca Cola at Dayton, Montgomery Ward and Sears Roebuck at Dayton, Standard Brands and General Baking at Dayton — to select but a few. In-

[20] *Ohio Agricultural Experiment Station, Bulletin 326*, p. 107.

[21] C. D. Dountz, Bartham Company, wool merchants, Columbus, Ohio, May 1, 1930.

[22] *Directory Textile Industries* (Bragdon, Lord, Nagel, New York), 1929.

creasing freight rates have tended to promote this form of decentralization in manufacture and distribution. But perhaps the greatest local manifestation of an attractive force is found within the machinery industry, dominant among valley manufactures.

This attractive force in the industrial organism of the middle valley may be known as functional magnetism. It is axiomatic that machine-using regions tend to become machine-making regions. The machine shop is the market for the machine tool, and the shop will be located where machinery is to be replaced or repaired. The Miami Valley has from the first been a thriving market for agricultural machinery, catering to the newly developing markets to the north and west. The satisfaction of this market has been largely responsible for the attraction of skilled mechanics, and, in turn, of new concerns dependent upon skilled mechanics.

Two possibilities here develop: first, inventions will be forthcoming from local mechanics and, second, subsidiary and allied industries will be attracted. Instances of both are known here. Four makes of automobiles have been manufactured, but have been eliminated in the selective development of this industry. Immediately after Dayton gave the world the airplane, its manufacture and that of parts and accessories flourished in and near it. Only one airplane continues in production. No matter what selection may have occurred, the machinery industry has risen in importance. Evidence of this is to be noted in these facts of the industry when compared with the average for other manufacturing plants:

1. There are four times as many men per plant.
2. More than four times as much value is added by the manufacturing process.
3. Nearly four times as much capital per plant is represented.
4. Twenty-three per cent of all tool shops are in the "largest" class with an output of $500,000 or more, as against only seven per cent for the average manufacturer.

"Thus the average machine-tool manufacturer took $1,111 in materials and fuel per wage earner and added $2,887 or 260 per cent of utility to it, in contrast to a 67 per cent increase in utility by the average manufacturer.[23] The Valley's dominant industry is developing along lines decidedly 'attractive' as a force in regional growth."

[23] E. F. DuBrul, executive secretary of the Machine Tool Builders Association, Cincinnati, Ohio, June 18, 1930.

Interregional Functional Convenience

Interregional functional convenience is represented in this industrial organism by the publishing houses of Crowell at Springfield and McCall at Dayton, which together turn out more than a million and a quarter of periodicals annually. Postal rates have been so zoned as to make decentralization or particularly favorable situations imperative for these and other periodicals with a national circulation. Other printing and publishing houses of lesser magnitude in Dayton likewise emphasize interregional convenience.

The manufacture of both rag and wood-pulp paper is predicated upon accessibility. With the growth of the trans-Appalachian country paper making became an industry in many places. For a generation after 1800 the Miami Valley, as the largest and most rapidly growing settlement in the Northwest Territory, witnessed the development of the greatest paper industry west of the Appalachians.

The canal period began the industrial selection which was to give individuality to local paper. Paper mills at Hamilton, Middletown, Franklin, Miamisburg, West Carrollton, and Dayton depended upon the canal for processing and power uses. Transportation was not a prime consideration, in view of the local character of the market and the scale of the industry as determined by scarcity of cotton and linen rags. The canal system made the Miami Valley so much more attractive for settlement that these paper mills were primarily concerned with keeping pace with the demand for paper.

Even before the close of the canal period these paper mills were drawing upon the vast reserve of underground waters for processing and for boiler uses. It was not subject to the varying volume and silted condition of river water. As a source of power, too, the canal was giving way to imported coal from southeastern Ohio and West Virginia. Yet the Miami River and canal, as localizing factors in the urban development of southwestern Ohio, continued to foster the manufacture of paper in spite of increasing competition with eastern producers and the initiation of other paper centers in the Lake states.[24] The trade is essentially less-than-carload in character, with national distribution; this is especially true of rag paper and of

[24] J. J. Hallowell, executive secretary of the Miami Paper Shippers Association, Middletown, July 2, 1930.

paper specialties, both of which are important phases of the local industry. Improvement upon the present location would be difficult.[25]

Parchment paper is sold to the dairying districts of New York, Wisconsin, Minnesota and Illinois; paper or "artificial slate" roofing is marketed through one of the two largest mail-order houses in the country; blotting papers are disposed of through many different sources, chiefly through advertising and supply houses; fine rag, ledger, and bond papers are sold everywhere. United States "penalty" envelopes are handled through governmental channels; the largest coated-paper mill in the valley supplies stock to lithographing and publishing houses throughout the United States.

On the other hand, phases of the paper market are distinctly local, as, for instance, a manufacturer of playing cards in Cincinnati contracts for the entire output of one paper mill: a local manufacturer of explosives and ammunition takes the entire output of one mill specializing in ordnance paper products.

Interregional functional convenience is perhaps better illustrated in the instance of industrial raw materials. In paper manufacturing, widely dispersed as is its market, the raw materials are more widely dispersed; white china clay used in coating paper comes from England and the Carolinas; the casein for adhesive comes from Argentina principally, with small amounts from France, New Zealand, and the United States; asphalt employed in roofing paper comes from Mexico and Trinidad; ground slate is from eastern Pennsylvania; sand from Illinois and Ohio; most of the cotton rags are from American cotton mills, although some are shipped from Japan: low-grade cotton and linen rags are received in bales from nearly all the larger cities of the United States; pulp wood comes from southern Ohio, the Ozarks, the Gulf States, and Canada; rosin is from Michigan and Ohio sawmills; chemicals are from many parts of this county, as are old papers and magazines for stock. The extent to which paper manufacturing is dependent upon transportation is well illustrated by the diversity and range of its raw materials, coupled with the relatively unimportant item of labor.

Manufacturers of pulp from rags followed the successful paper-

[25] E. K. Hunt, Champion Coated Paper Company, Hamilton, August 22, 1929; West Carrollton Parchment Company, August 31, 1929; George Mead, Mead Paper and Pulp Company, Dayton, August 31, 1929.

makers in the middle valley; three of them are left in competition. Manufacturers of papermaking machinery have managed to capitalize upon the functional magnetism which was a potent factor in their initiation. Of this group there are two large and five smaller concerns now in operation.

Human Factor

The human factor serves as a centripetal force in this industrial organism. The manufacture of paper calls for the use of a very long woollen blanket or "felt" with hand-woven seams. Warp threads must be strong and woof threads must be thick and absorbent. Only wool fiber is satisfactory, since the wet cellulose does not cling to wool.

Some seventy years ago a woollen mill in the Miami Valley discovered a way of making these heavy woollen blankets so that their normal life was more than trebled. The result was a specialization in certain of the woollen mills and advance in the manufacture of paper, both of which were of incalculable importance to the longevity of valley paper and woollen mills in the face of competition with other centers.[26]

To the manufacture of machinery, the valley's most important industry, the labor supply is a vital factor. A certain labor turnover in these machine-making industries is to be expected, but the neighboring automobile factories of Toledo and Detroit attract these men by somewhat steadier employment.[27] Surrounded by the rich farming region, cities and towns enjoy extraprofessional activities and savings which constitute psychic income; this advantage is invariably given by the wage earner questioned. Labor drawn from the adjacent counties is preponderately native-born white and is notably free from labor troubles. For the lowest grade of work labor comes from the hilly counties of northeastern Kentucky.[28]

The turbine was invented and is manufactured in Springfield. Electrical refrigeration was the invention of a resident of the middle valley. The airplane was the product of Dayton residents, although

[26] Paul Benninghofen, Miami Woolen Mills Company, Hamilton, Ohio, May 3, 1929; T. E. Jones, Harding-Jones Paper Co., Excello, May 3, 1929.

[27] DuBrul, June 18, 1930 (see note 23).

[28] J. W. Quigley, vice-president of the Logan-Long Paper Company, Franklin, Ohio, August 2, 1929; G. M. Verity, President of American Rolling Mill Company, Middletown, August 2, 1929.

its manufacture has had a lingering demise locally. The cash register and the ignition system which formed the basis for the employment of ten thousand men in these two industries today were invented and developed by Miami Valley mechanics.

Of perhaps greater importance is the fact that these industries have been training hundreds and thousands of workers who become available for other industries that require such skilled labor.[29]

While the land surface and the crops of the Miami Valley invited the use of labor-saving machinery for farm work, the nature of the people constituted an important factor in industrial location in this region of good farms and good farmers.

The invention of the reaper, binder, and cultivator took place after canals had been built. Although none of these was a local invention, their use here was early and extensive. The valley has always presented a vigorous market for farm implements, the satisfaction of which was largely responsible for the manufacture of improved agricultural machines.

Inventions have been noted previously as centripetal forces, but the presence of unemployed farm labor due to seasonal farm work or mechanization of farm work has a dispersal effect upon manufacturing. For example, the manufacture of shoes is carried on in branch factories in several towns and small cities served by a railroad and offering cheap labor. The transfer of skill to a machine has enabled this industry to respond to the decentralization of its market and its labor supply, largely unskilled.

Tobacco factories further exemplify this symbiotic relationship. The type of labor is much the same. Further examples of this decentralization of labor, predicated upon the part-time aspects of farming and the symbiotic relations with industry, are noted in the canning of sweet corn, vegetables, and fruits.

CONCLUSION

Lying athwart the prevailing path of settlement and commerce, this valley has continued to develop along the original settlement

[29] Testimony by presidents of the following concerns: Buffalo-Springfield Roller Co., Springfield, July 21, 1929; American Rolling Mill, Middletown, July 23, 1929; Black-Clawson Paper Mill Machinery Co., Hamilton, July 23, 1929; and Niles Tool Works, Hamilton, July 25, 1929.

pattern. The fertile soil and the gently rolling surface have invited an agricultural occupation which even during the period of appropriation was diffused over the entire middle valley. Only the agricultural attachments of manufacturing were fostered. It took the canal period, with its accelerated growth in population and increased accessibility, to initiate the industrial forces which have, during the process of its utilization, resulted in a strongly individualized region.

The essential basis for the modern industrial organism of the middle valley took form during this period: a uniformly dense agricultural occupation of the area, localization of the major towns along the river, and, finally, the mechanization of farm work.

The variety and distribution of raw materials consumed in these manufacturing industries have been related to the spectacular development and use of farm and industrial machinery. The valley took in its stride the changing sources of raw materials and of markets, but of even greater significance to the character of its present industrial structure have been the industrial forces, wholly apart from materials, which have developed within the region.

In the periphery the scores of towns and villages have experienced an industrial change which, in the main, has been uprooting and is manifested by local industrial relicts.

In the industrial core of the valley such forces have given to the manufacturing processes of the region these relative qualities: first, a high value added by the manufacturing process, second, an emphasis upon precision machinery, and, finally, a widely ramified market.

In this small area the items of human occupance focus upon the cities of the middle valley, and the resulting industrial structure is an appraisal of the inseparable connection between these centers and their agricultural setting. As the area has become more complex in its economy, its regionality has become more pronounced through a dispersal of wage earners in plants offering increasingly more wage jobs.

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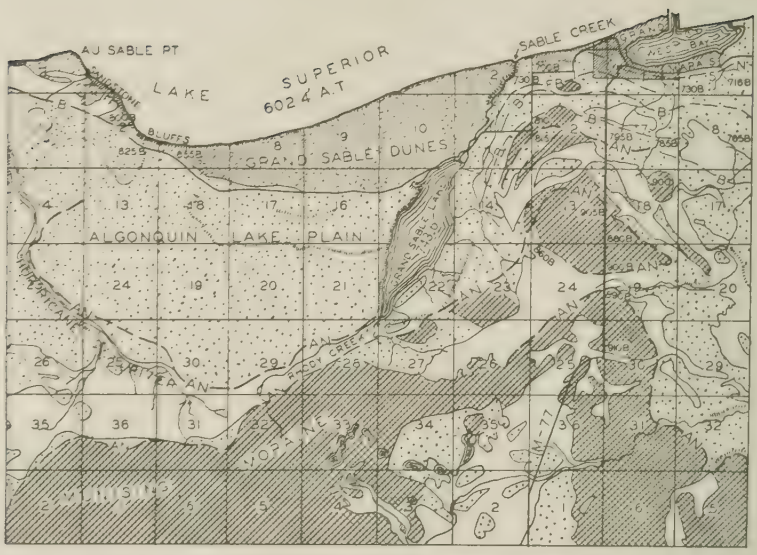
Columbus, Ohio

THE GRAND SABLE DUNES ON LAKE SUPERIOR, ALGER COUNTY, MICHIGAN

STANARD G. BERGQUIST

THE Grand Sable dunes, situated to the west of Grand Marais (see Map 33) occupy an area of approximately five square miles along the shore of Lake Superior in T. 49 N., R. 14 W. Although limited somewhat in areal extent, this dune massif has in part suffered extensive morphological changes since its development in the early stages of Lake Algonquin history and presents a topography which has been made extremely complicated by aeolian erosion (see Pl. XLVI, Fig. 1). The area lies some distance to the north of the hinge line and bears evidence of having been raised 275 feet or more by differential uplift since early Algonquin time. The present dunes are perched partly upon a bay-mouth[1] bar with a steep, wave-modified front slope extending down to Lake Superior. The bluff face along the lake shore exposes a cross section (Fig. 21), which reveals an interesting succession of glacial and glaciolacustrine deposits (Pl. XLVI, Fig. 2). In the basal portion of the shore cliff, extending upward 100 feet or more above the level of Lake Superior, the material is boulder clay or till of strictly glacial origin. Large erratics are scattered promiscuously through this section and form a prominent part of its composition. Numerous large boulders are strewn upon the present strand and likewise are distributed over the floor of the lake for some distance out from the shore. Where the water is shallow, they project above its surface. The erratics and coarse cobbles were here concentrated by the attack of waves against the shore cliff while the finer material was being carried away. Their distribution on the lake floor serves to give a general index of the amount of retrogression suffered by the shore since Algonquin time. Resting upon the basal till sheet and extending to the surface of the bar is a series of stratified beds and lenses composed of rounded cob-

[1] Johnson, D. W., *Shore Processes and Shoreline Development*, First Edition (John Wiley and Sons), pp. 300–307. 1919.



MAP SHOWING LOCATION OF GRAND SABLE DUNES

- MORAINE
- LAKE PLAIN
- SAND DUNES
- ROAD
- BLUFFS
- ROCK LEDGE
- SHORE LINE
- NIPISSING
- FORT BRADY
- BATTLEFIELD
- ALGONQUIN
- ·700′ – ELEVATION

SCALE

1 ¾ ½ ¼ 0 1

Map 33

bles and coarse gravels, intercalated with silt and sand of varying degrees of texture. This composite of assorted and stratified material which constitutes the upper section of the exposure is lacustrine in origin and was deposited during the early stages of Lake Algonquin history. The surface of the bluff near the outer or lakeward margin of the plain stands at an altitude of 870 to 880 feet above sea level and is composed essentially of wind-worn gravel and cobble.

In an early stage of glacial lake history the Algonquin waters formed a shore which is now marked by a wave-notched cliff, at an

altitude of 880 feet, in the moraine two miles south of Grand Marais. During this time a bay-mouth bar, constructed across the mouth of a large embayment, was extended between the rocky headland of Au Sable Point and the rock falls near the mouth of Sable Creek. The lagoon which formed between the bar and the shore line was originally rather large, but gradually dwindled in extent as differential uplift

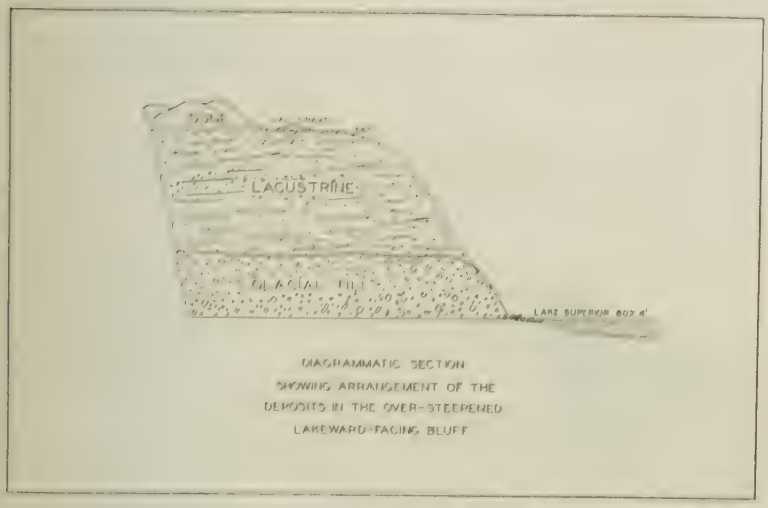


Fig. 21

raised the land and drainage changes caused a lowering of the lake level. Grand Sable Lake, with an altitude of 743.6 feet or 141 feet above the level of Lake Superior, is a remnant of this former large, land-locked lagoon (Fig. 22).

In the interval during which the early Algonquin waters receded to a level slightly below that of the newly formed bar, the waves of the lake were actively engaged in propelling large quantities of sand shoreward. Storm waves especially were responsible for the beaching of sediment high up on the strand, beyond the reach of normal wave action. The beach sand supplied by waves to the Algonquin bar dried out intermittently and in the desiccated condition was shifted to the windward by atmospheric circulation. Although there are now no evidences that the original wind-blown sand deposits were laid down

as fore-dune ridges, it is logical to assume that the Algonquin aeolian cycle was in its various aspects quite similar to that which characterizes later dune activities as discussed by Miss Stevenson.[2] Fore-dune ridges were without doubt originally piled up as low features running parallel to the shore. These then supplied material out of which the larger "strand" [3] dunes were subsequently formed.

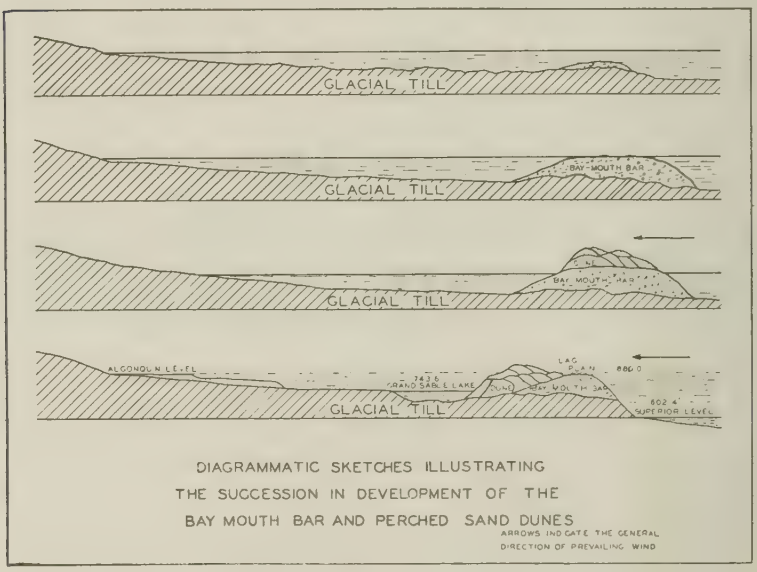


Fig. 22

From the viewpoint of structural characteristics the dunes of the Grand Sable region may logically be subdivided into two units. In the western extremity of the area the growth of a dense stand of hardwoods has definitely restricted migration. Here the dunes are arranged in successive rows, each trending parallel to the shore line of Lake Superior. They were whipped up into definite ridges with an axial trend more or less normal to the direction of the prevailing north-

[2] Stevenson, Ellen B., "The Dunes of the Manistique Area," *Pap. Mich. Acad. Sci., Arts and Letters*, 14 (1930) : 475–485. 1931.

[3] Solger, F., and Others, *Dunenbuch* (Verlag von Ferdinand, Enke in Stuttgart), pp. 141–147. 1910.

westerly onshore winds which formed them, and they correspond to the transverse type as described by Au-frère.[4] In this section the dunes have suffered but slightly from the effects of deflation and show little or no evidence of having been greatly deformed.

In the section which lies immediately adjacent to Grand Sable Lake there is a scarcity of forest cover, and the wind has played havoc with the sand deposits. A study of this area in broad perspective reveals a rather indefinite transverse arrangement of the original dune ridges, although an attempt to trace them out is futile. Earlier transverse dunes were doubtless formed during the Lake Algonquin stage, when the waves contributed to the beach a constant supply of sand for aeolic translocation. When the land was uplifted to the point where the water level dropped too low for sand to be carried up to the bar by the waves, the dunes were detached from their source of supply and constructional activity terminated. With the source of fresh sand cut off, aeolian energy was directed largely to reworking the material of the dunes already formed. In post-Algonquin times the original transverse ridges have been thoroughly transected by the strong, turbulent winds blowing landward from Lake Superior. Deep deflation furrows and wind troughs have been sculptured in the old sand surface, and in places sand removal has been sufficiently complete to expose the underlying lacustrine bar gravel and often the basal till. In the deeper blowouts, and particularly where they have been excavated into the till below the cobble and gravel, the floors support a dense stand of young evergreens, which seem to have a stabilizing and controlling influence on local sand movements.

The dune surface in the Grand Sable lake section has been made so complicated by wind erosion that it is now difficult, if not impossible, to determine any well-defined pattern of structure. So completely have the original transverse dune ridges been deformed by wind activity that it is impossible to trace them except for very short distances. They have been reconstructed by erosion and translocation, as suggested by Free,[5] into secondary ridges which run more or less parallel to the prevailing wind direction, types which Au-frère [6]

[4] Au-frère, L., "Le Cycle morphologique des dunes, "*Annales de Géographie*, 40 : 362–385. 1931.

[5] Free, E. E., *The Movement of Soil Material by the Wind, with a Bibliography of Aeolian Geology by S. G. Stuntz and E. E. Free,* U. S. Bureau of Soils, Bull. 68, pp. 1–173. 1911.

[6] Au-frère, as cited in note 4.

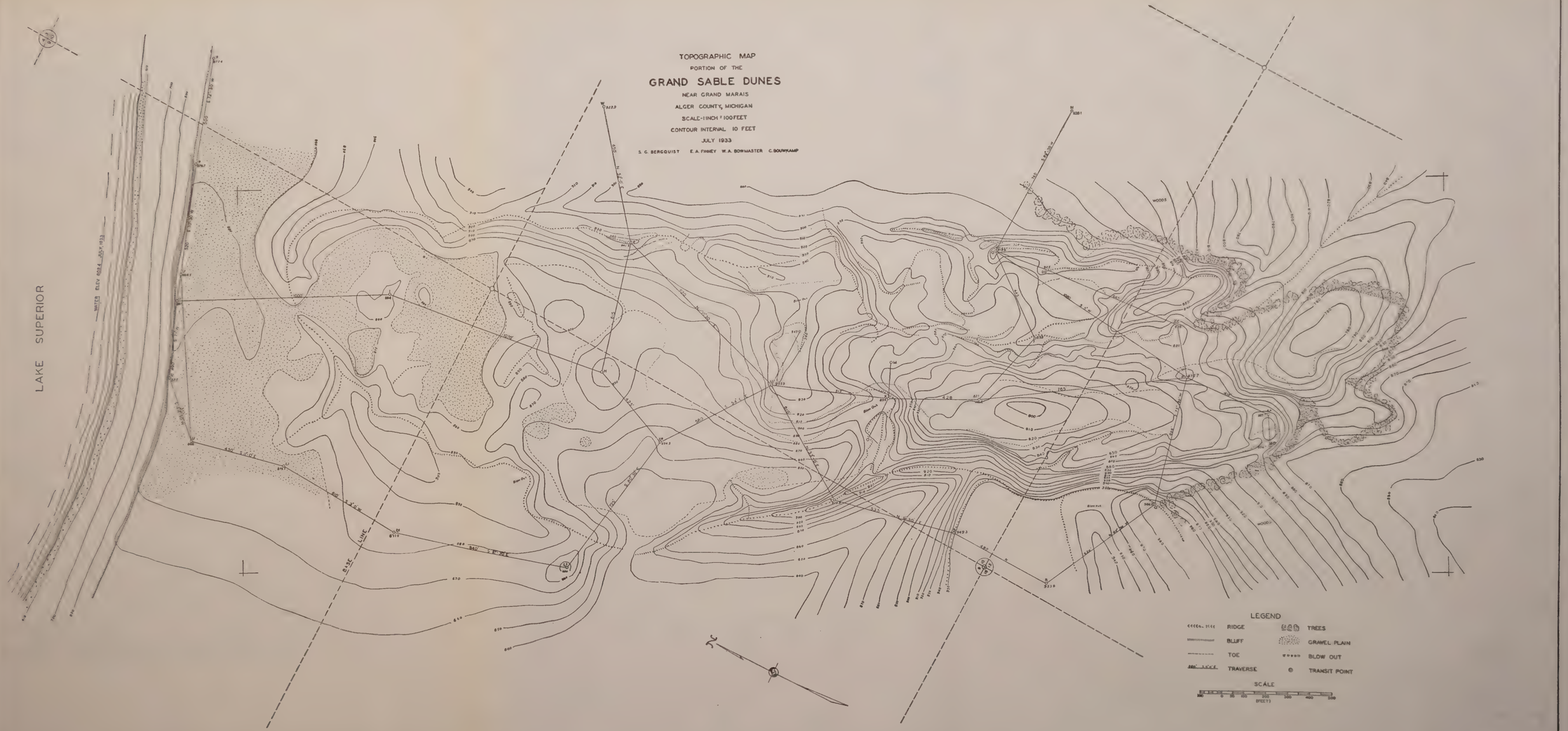
classifies as longitudinal. It is rather singular, however, that the transitional or horseshoe type of dune which Scott[7] has found in many of the Nipissing areas along Lake Michigan is lacking in the Grand Sable lake section. This may be due to the fact that the wind-exposed Algonquin dunes, being older, have been subjected to much more deformation than those of Nipissing age. Consequently they have passed through and beyond the transitional stage of development.

The longitudinal dunes of the area are rather rugged in relief (see Map 34). The highest dune observed was found to have an altitude of 980 feet above sea level, while the deepest deflation hollow was 200 feet lower. The ridges have a general trend N. 30°–40° W., S. 30°–40° E. and are separated from each other by deep aeolic valleys or wind furrows. Their slopes are greatly oversteepened and maintain angles up to 60 degrees, especially where dune grasses and trees are effective in holding the sand particles together. The crests of the dunes terminate occasionally in knife-edge ridges, particularly where the deflation surface is freshly developed on older slopes upon which grasses have had an opportunity to extend a well-formed root system.

One of the factors contributory to the development of steep slopes is associated with the activities of melting ice and snow. During the winter season snow accumulating on the sand surface often becomes buried under several feet of drifting sand. The weight of the sand cover, together with the impacting force of the wind, has a tendency to transform the snow into a partly frozen ice. The insulating influence of the sand delays melting of the underlying ice for a considerable period after the surface snows have completely disappeared, and it is not uncommon to dig into buried ice as late as the middle of June. When finally the subsurface ice melts out on the slopes, large masses of water-soaked sand break off along well-formed and somewhat extended cracks and joints. These slump downward and produce new slopes considerably steeper than the angle of repose for the material contained.

The dunes which have been blown up rather recently, or which are now in process of formation, especially in the aeolic valley ways, show evidence of sculpturing by two principal wind directions more or less opposed to each other. In the majority of the newly formed larger dunes the steep back slopes face to the southeast, indicating a pre-

[7] Scott, I. D., personal communications.


TOPOGRAPHIC MAP
PORTION OF THE
GRAND SABLE DUNES
NEAR GRAND MARAIS
ALGER COUNTY, MICHIGAN
SCALE-1 INCH = 100 FEET
CONTOUR INTERVAL 10 FEET
JULY 1933
S. G. BERGQUIST E. A. FINNEY W. A. BOWMASTER C. BOUWKAMP
LAKE SUPERIOR
WATER ELEV 602.4 JULY 1933
LEGEND
RIDGE
BLUFF
TOE
TRAVERSE
TREES
GRAVEL PLAIN
BLOW OUT
TRANSIT POINT
SCALE
WOODS

Map 34

vailing northwesterly wind from Lake Superior. Some of the smaller dunes have their steep lee slopes reversed in direction and give evidence that the weaker land winds likewise have played an important rôle in modeling the surface relief. The present complex topography of the area is the product of continued post-Algonquin operation of these opposing aeolic forces, with the advantage greatly in favor of the much stronger onshore winds.

The general absence of a vegetative cover in the Grand Sable lake section of the dunes has been and still is responsible for a considerable amount of migration of sand by the wind. Immediately to the north and east of the lake a forest is now in process of being invaded by drifting sand (Pl. XLVII, Fig. 1). Here the deposit has piled up to such a depth as to cover completely the smaller trees, while the larger ones stand buried to half their total heights. The channel of Sable Creek, which forms the outlet of Grand Sable Lake and likewise limits the eastern margin of the Algonquin dunes, is being continually shifted to eastward by the rapidly invading sand (Pl. XLVII, Fig. 2). Farther to the west the dunes are gradually encroaching upon the margin of Grand Sable Lake, and much sand is annually being driven by the wind into its basin (Pl. XLVIII, Fig. 1).

On the bar, along the Superior shore, where the perched dunes are relatively low or absent, and the sand mass is limited in volume, the wind has successfully removed the bulk of the finer débris, with the result that in local areas the gravel surface has been swept fairly clean of sand (Pl. XLVIII, Fig. 2). Along these margins the coarse cobble and gravel are concentrated on the residual floor to form the so-called lag gravel of Udden.[8] In certain of these areas once buried forests are now being exhumed by the wind (Pl. XLIX, Fig. 1).

On the wind-exposed marginal tracts, where the finer particles have been whipped across the desert armor of the bar, the long-continued process of sand blasting has sculptured the cobble, gravel, pebbles and even the smaller granules to produce a variety of wind-worn stones described as ventifacts by Bryan.[9] Many of the fine-grained stones, such as granite, diorite, diabase, and basalt, have been faceted by wind-driven sand blasts into the characteristic *Ein- und*

[8] Udden, J. A., *Mechanical Composition of Wind Deposits*, Augustana Library Publication, No. 1. 1898.

[9] Bryan, Kirk, *Wind-Worn Stones or Ventifacts. A Discussion and Bibliography. Reprint and Circular Series of the National Research Council* (Report of the Committee on Sedimentation, 1929–30), No. 98, pp. 29–51.

Dreikanter of German literature (Pl. XLIX, Fig. 2). The coarser-textured rocks, such as pegmatite and coarse granite, have had their softer minerals etched deeply by the blasting action of the wind, but the more resistant minerals stand out in bold relief (Pl. L, Fig. 1). Although acres of wind-polished ventifacts of various shapes and sizes are exposed along the margin of the lag-gravel plain near Lake Superior, there seems to be no definite or systematic orientation of the faceted planes. This may undoubtedly be accounted for by the fact that the armored surface is exposed to the activities of the variable landward and lakeward winds, which have a tendency to shift the sand across the surface in all directions.

In the deflation hollows or blowouts the atmosphere is constantly forced into a turbulent activity as a consequence of cross currents and eddies which are set up by the lashing gales of Lake Superior. In the areas of turbulence a great deal of fine material is constantly being lifted into the atmosphere and carried away by flotation. The continued movement of the wind across the sand surface produces ripples (Pl. L, Fig. 2), which appear to vary in size according to the texture of the particles and the velocity of the wind. These range from minor wrinkles in the finer sand to the giant waves of Bucher [10] in the coarser material. For each different wind velocity there is a given textural range of material which is moved *per saltum*. The index of the ripples, or the relation between wave length and wave height, is determined largely by these factors. One of the largest giant ripples to be observed after a severe wind measured seven feet from crest to crest and had a wave height of fourteen inches. This wave possessed a basal composition of coarse sand, which was veneered with faceted and polished fragments ranging in size from coarse gravel to angular pebbles an inch and more in diameter. It is difficult to conceive of a wind turbulence sufficiently violent actually to move, for any great distance, particles so large. The writer is of the opinion that the coarser material originally formed a protective mantle over the underlying sand surface. The wind blowing through the open network of pebbles and gravels had a tendency to move the finer material below, and to cause it to assume a rippled surface. The coarser fragments above merely settled into the newly developed structure and in conformation with it. Further studies of wind veloci-

[10] Bucher, W. H., "Giant Ripples as Indication of Paleogeography," *Proc. Nat. Acad. Sci.*, 3: 285–291. 1917.

ties and sand movement during periods of severe atmospheric disturbances are necessary before definite conclusions may be reached in regard to the mechanics involved in the distribution of the coarse material in such rippled surfaces.

The Grand Sable dunes terminate in the central portion of Section 7, T. 49 N., R. 14 W. At this point and continuing westward for a distance of about a mile the dunes give way to the steeply sloping Grand Sable banks. In profile, this section is similar to that which constitutes the area where the dunes repose. It is composed of stratified layers and lenses of cobble, gravel, sand, and silt, resting on basal till, and is merely a continuation of the bay-mouth bar which connects at this end with the rocky headland of Cambrian sandstone at Au Sable Point. The bluffs stand at an altitude of 875 feet and slope northward down to Lake Superior with an average angle of 35 degrees.

The crest of the banks is a wind-swept sandy plain over the surface of which are scattered groups of low aeolian sand hills. It is quite probable that well-defined dune ridges were originally formed on this portion of the bar during the Algonquin stage. Owing to the fact that it represents the narrowest portion of the wave-deposited feature, the dunes have been moved off and destroyed through propulsion of sand by the dominant winds after removal of the source of sand supply. Evidences of considerable translocation by wind activity are to be found in the sandy lake plain, extending southward into the Hurricane Basin, where the surface is mantled with a thin covering of wind-deposited sand.

CONCLUSIONS AND SUMMARY

A study of the geological evidences which are available in the area seem to permit the following conclusions:

1. The Grand Sable dunes were formed from contributions of sand deposited by wave action upon a bay-mouth bar, the surface of which corresponds in level with the position of an early Algonquin stage in lake history.

2. Differential uplifts since Algonquin time have raised the bar some 275 feet to an altitude of 880 feet above sea level. In the process of uplift, accompanied successively by lowering of the lake level, a large lagoon, formed between the bay-mouth bar and the older shore, eventually contracted to produce Grand Sable Lake.

3. When the level of Lake Algonquin was lowered sufficiently to

cut off permanently the supply of fresh sand, dune accumulation ceased, and the wind was forced to direct its energies largely in translocating the sand of the dunes already formed.

4. The original dunes in the area where migration has been most pronounced were undoubtedly of the transverse type. They have subsequently been transected by deflation with the development of longitudinal forms which are separated from each other by deep wind furrows.

5. Because of their age the dunes of the region have suffered so much deformation that no vestiges of fore-dune ridges are preserved. Likewise they have passed from the transverse to the longitudinal forms leaving scarcely any traces of the intermediate stages.

6. The dunes in the Grand Sable lake section are actively migrating windward, with the result that the sand is gradually being removed from the original position on the bar. Extensive areas of the marginal tracts fronting Lake Superior have been swept fairly clean of sand by the activity of the dominant winds. In time the dunes will be shifted so far to the southward that the bar will be largely, if not completely, exposed.

Michigan State College
East Lansing, Michigan

FIG. 1. A general view of the dunes in the Grand Sable Lake section. Photograph by L. C. Hulbert

FIG. 2. A section of the bluff exposure on the lakeward face of the bay-mouth bar. Note the Nipissing–Algonquin shore cliffs and terraces in the background

FIG. 1. Sand dunes invading a forest to the west of Grand Sable Lake.
Photograph by L. C. Hulbert

FIG. 2. Sand dunes intruding upon Sable Creek, the outlet of
Grand Sable Lake

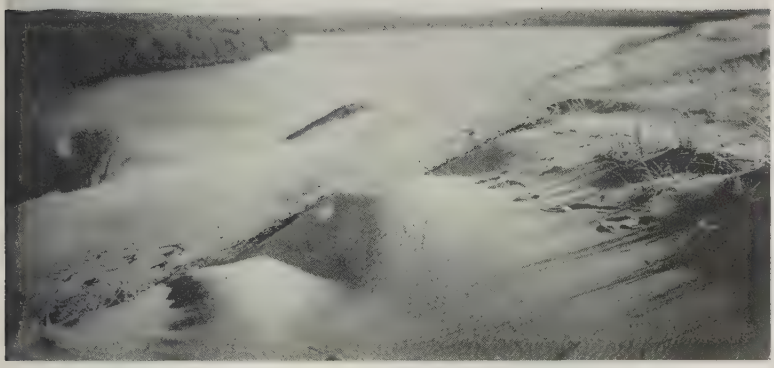


FIG. 1. Migrating dunes encroaching on the shore of the north end of Grand Sable Lake. Photograph by L. C. Hulbert

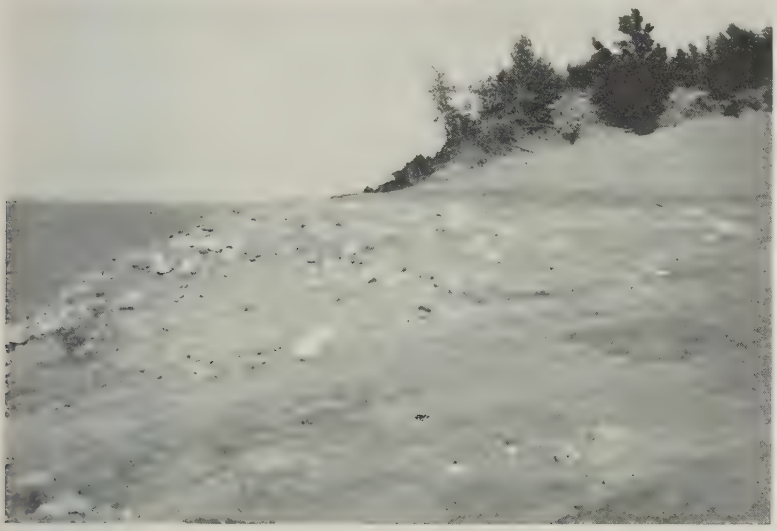


FIG. 2. Surface of cobbly-gravelly wind-swept bar, showing perched dunes in the background

FIG. 1. Resurrected forest in sand-dune section on the bay-mouth bar, near Lake Superior

FIG. 2. Faceted cobbles from the lag plain of bar, near Lake Superior

PLATE L

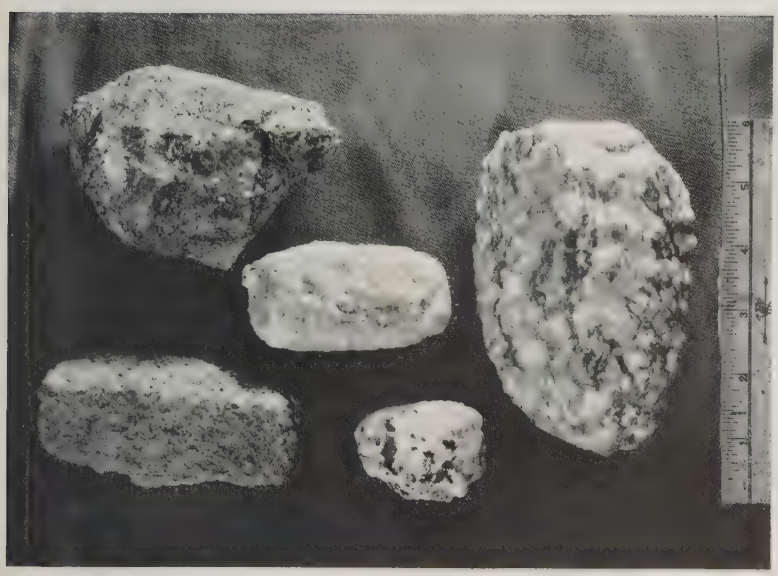


FIG. 1. Etched and partly faceted cobbles from the lag plain of bar, near Lake Superior

FIG. 2. Wind-rippled surface in migrating dune. Photograph by L. C. Hulbert

SINKHOLES IN THE INDIAN LAKE REGION, SCHOOLCRAFT COUNTY, AND OTHER MICHIGAN SINKS

O. FLOYD POINDEXTER

IN A paper presented at the 1934 meeting of the Michigan Academy mention was made of certain depressions about one mile southeast of "Big Spring," Schoolcraft County (see Pl. LI). At that time these depressions had been observed in airplane photographs, but had not been studied in the field. Last September I had the opportunity to revisit the Big Spring region, and with the assistance of Mr. Stanley Reid, caretaker of the Palms Book State Park, and Mr. Joseph Dupont, an old lumberjack, examined about twelve of these depressions.

The larger holes range from 100 to 150 feet across and from 40 to 50 feet in depth; the dimensions are approximately those of the Big Spring depression, which appears to be formed from two sinks which intersected each other during the slumping-in process. There are also smaller holes 50 feet across and 15 to 20 feet in depth, as well as still smaller pits 15 to 20 feet across and 6 to 8 feet in depth. The depressions are sharply conical; the large ones, which taper to a width of only 6 or 8 feet at the bottom, suggest an opening in the rocks below, into which the sandy soil has poured in hourglass fashion. As a result of recent heavy rains most of the holes contained water at the time of the visit. This imperviousness of the bottom is explained as due to a silting up of fine material washed down the slopes by rain. Leaf mold, which has accumulated to a depth of three feet in most of the depressions, also aids in retarding drainage at the bottom of the holes.

Direct evidence of formation of the holes by caving in of the surface formations was found along the old railroad grade that passes through the sinkhole area. This grade is heavily grown up with grass and weeds, but at the very center there is a tubular opening about four feet in depth and large enough to admit a man's body. At one

side of the opening the soil has slumped, and a fresh break in the sod is plainly observable. Mr. Dupont stated positively that the break in the grade was not in existence at the time of his last visit, which was about one year previous. The stable character of the old logging grades of the north, the absence of any fill at that particular point, and the heavy sod which has developed preclude the possibility of the depression having been formed by slope wash or gullying.

In a previous paper by the author [1] it was suggested that Big Spring was formed as a result of slumping of the rock strata and overlying surface drift owing to solution of beds of gypsum at the top of the Cataract (?) formation. This created an avenue along which the heavily charged calcium sulphate waters might rise.

The surface drift of the area of Big Spring and the sinkholes to the south is underlain by rock strata of the Burnt Bluff formation, which in the eastern part of Schoolcraft County contains important beds of high calcium limestone. Westward these beds have become dolomitized, but locally undolomitized areas exist. Outcrops of nodular semilithographic limestone were found on the east side of Indian Lake only a few miles from the site of the sinkholes. An alternate theory of the origin of Big Spring may be developed by postulating solution of local limestone areas in the Burnt Bluff formation and establishment of a connection with lower beds by downward movement of surface waters, which enlarged joint cracks and other passages. In the case of the sinks to the south of the spring no deeper connection would be assumed to have been established.

In the Southern Peninsula spectacular sinkhole development has taken place in Presque Isle, Alpena, Montmorency, Otsego, and Cheboygan counties; the sinks occur in the belt of outcrop of the Traverse limestone (see Map 35). The best known of these sinks are in Presque Isle and Alpena counties. Just east of Shoepac Lake in Presque Isle State Forest there is an arcuate group of five very deep sinks (Pl. LII) that lie in a valley which can be traced eastward for a distance of several miles. Several other sinks are located in the eastward extension of this valley, and others are unrelated to the valley. Sink No. 1, which is 500 feet west of Shoepac Lake, is 120 feet deep, and the bottom is *90 feet below the water surface of the lake.* All

[1] "A Study of Underground Waters Bearing on the Source of 'Big Spring,' Schoolcraft County, Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 20 (1934): 477–483. 1935.

the holes are completely dry, and have a growth of jack pine and poplar in the bottom.

Michigan Emergency Conservation workers sank a 20-foot pipe in the area between the lake and the sinkholes. The test showed that the upper 20 feet of the surface drift is composed of a tight sandy clay which undoubtedly holds the lake in a higher position than the normal

Map 35. Sinkhole areas (shown by circles) in the northern part of the Southern Peninsula

water table in that area. Francis Lake drains through Tomahawk Creek into Black River, but Shoepac Lake has no visible outlet. Initial inspection of airplane photography suggested that, because of the existence of the valley eastward from the lake, Shoepac Lake originally had a surface outlet down this valley to the Rainy River system until the sinks developed, captured the water, and left the outlet dry. Examination of the pictures under the stereoscope and of the area in the field, however, refuted this theory because of the height of the ridge between the lake and sink No. 1, and the absence of river terraces and other features in the valley east of the sinkholes. The valley presents a flattened U-shaped cross section, and its bottom has a hummocky rolling character.

It is believed that this is a valley sink and that Shoepac Lake at an early stage developed underground drainage lines that followed the direction outlined by the surface valley, at least until the development of the deep sinks. It is quite possible that a small preglacial valley existed in the limestone and that the drainage from the later-formed glacial lake sought out this old valley and, as time went on, gradually sank through cracks in the limestone and became largely underground, with an eventual slumping in of the blocks of limestone along the drainage line. This settling and caving clearly occurred after the area had been uniformly covered by glacial materials. Aërial photographs of the valley east of the sinks disclose the presence of parallel ridges or undulations on the side of the valley which could have been formed by slumping or settling of the glacial materials. Some of these ridges have the appearance of distinct breaks in the soil.

Little Ocqueoc River near Millersburg, Presque Isle County, shows how a stream sinks into enlarged cracks in limestone and eventually flows underground, leaving a dry surface channel into which blocks of limestone have slumped as a result of undermining by solution.

The most extreme development of sinkhole topography in the several counties mentioned, and probably the most impressive, is found near Long Rapids, Alpena County. Here nine sinks can be viewed in a distance of one-half mile along the road. Six of these have vertical walls of limestone. In Fletcher State Park, about six miles north of the village of Long Rapids, is the famous Sunken Lake (Pl. LII), a valley sink with a funnel-shaped sinkhole at the western end. This appears to be a preglacial valley sink, since the north wall is heavily covered with glacial drift, whereas the south wall is an almost vertical limestone cliff. In the spring, when the rivers were high, Sunken Lake was filled with water by overflow from the North Branch of the Thunder Bay River. By late summer, however, the water had all disappeared through cracks in the rocks and through the sinkhole in the west end of the valley. A dam built in the lumbering days to prevent logs from being diverted from the main channel of the river into Sunken Lake now leaves this part of the valley permanently dry.

Ver Wiebe [2] has emphasized the occurrence of acervularia reefs in the limestone walls of the sinkholes of Alpena County as having a bearing upon the localization of the sinks. This seems to be a plausi-

[2] Unpublished manuscript, "The Stratigraphy of Alpena County, Michigan."

ble theory, since the extreme purity of the reefs favors solution, and their more or less domelike structure and tendency toward alignment or grouping would account for the roughly circular outline of the sinks and their frequent occurrence of three or more in line or in a group.

An interesting phenomenon noted by Rominger as early as 1876 may be observed at the outlet of Long Lake in northeastern Alpena County. Here is a three-armed lake of peculiar appearance (Map 36)

Map 36. Long Lake, Devils Lake, and Long Lake Creek, Alpena County

that was probably formed by solution along joint cracks and subsequent settling along the lines of solution to produce the right-angled pattern. In the spring and early summer, when the outflow from Long Lake is large, Devils Lake fills with water, and the bulk of the drainage apparently goes by way of Long Lake Creek to Lake Huron. In midsummer, however, the outflow from Long Lake diminishes, the level of Devils Lake drops rapidly, and by late summer not only is the lake almost entirely dry but the drainage to Lake Huron *has been reversed*, and the entire outflow from Long Lake can be observed to disappear underground in a funnel-shaped depression in the south arm.

An interesting sink known as "Deep Hole" is located in El Cajon or Misery Bay. The water at the head of the inlet to this bay is very shallow, averaging only a few feet in depth. At the rim of the sinkhole, however, the ledge drops off abruptly to a depth of 76 feet. Grabau [3] states that strong springs arise from this depression, and legend has it that the water which formerly disappeared at Sunken Lake reappeared in Misery Bay. If any definite underground stream issues at this point, however, it would seem more logical that it should come from the Long Lake outlet rather than from more distant Sunken Lake.

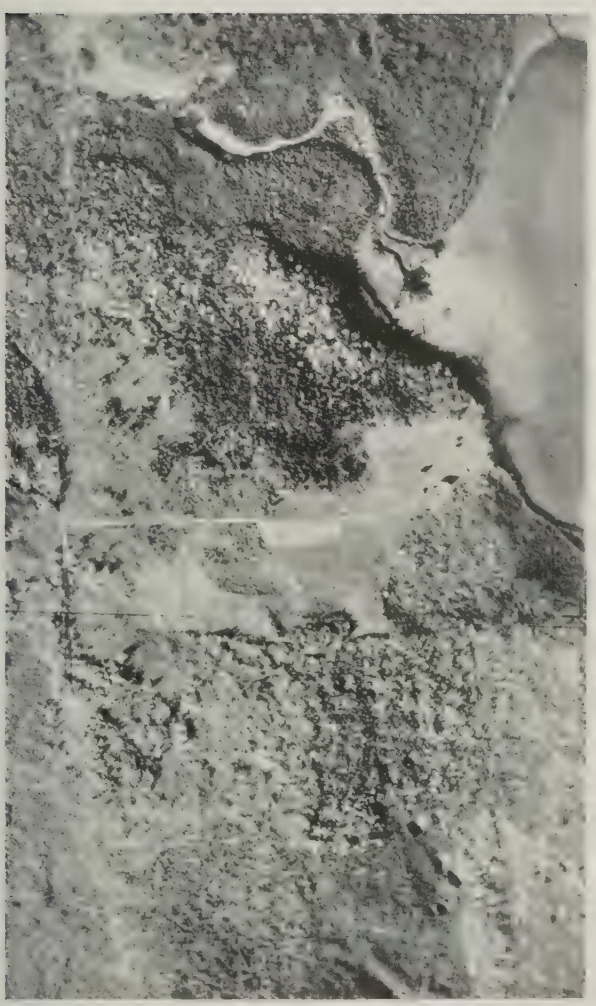
In the Pigeon River Forest, northeastern Otsego County, there is a group of extremely interesting lakes strikingly circular in outline, lying in deep holes in an outwash plain (see Pl. LIII). The sides of the basins slope precipitously to the water surface, which lies from 50 to 60 feet below the rim of the hole, and the water has an equal or greater depth. One of these holes is known as the "Devil's Soup Bowl." These depressions are considerably larger than any of those mentioned before; the larger holes are more than 600 feet across. These depressions are thought to be sinkholes in the Traverse limestone, as it is otherwise difficult to account for the nearly circular funnel-like form, steep sides, and so nearly similar characteristics of this group of lakes.

Professor S. G. Bergquist [4] states that sinkhole topography is present in the northwestern part of Montmorency County. This development in the form of deeply pitted outwash apparently is related to that of the Shoepac Lake area, which it adjoins.

Department of Conservation
Lansing, Michigan

[3] *Geol. Surv. Mich., Ann. Rep. for 1901*, p. 187. [4] Oral communication.

PLATE LI



Aërial photograph of sinkholes near Indian Lake, Schoolcraft County (lower right-hand corner). Big Spring is in upper left quadrant

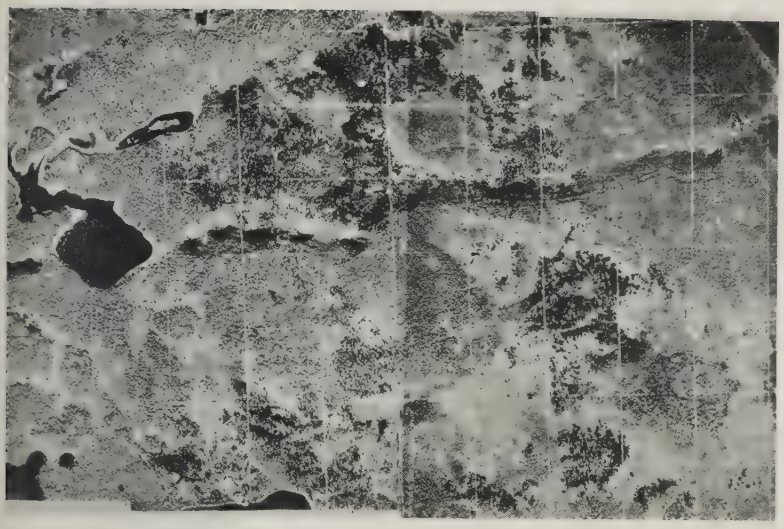
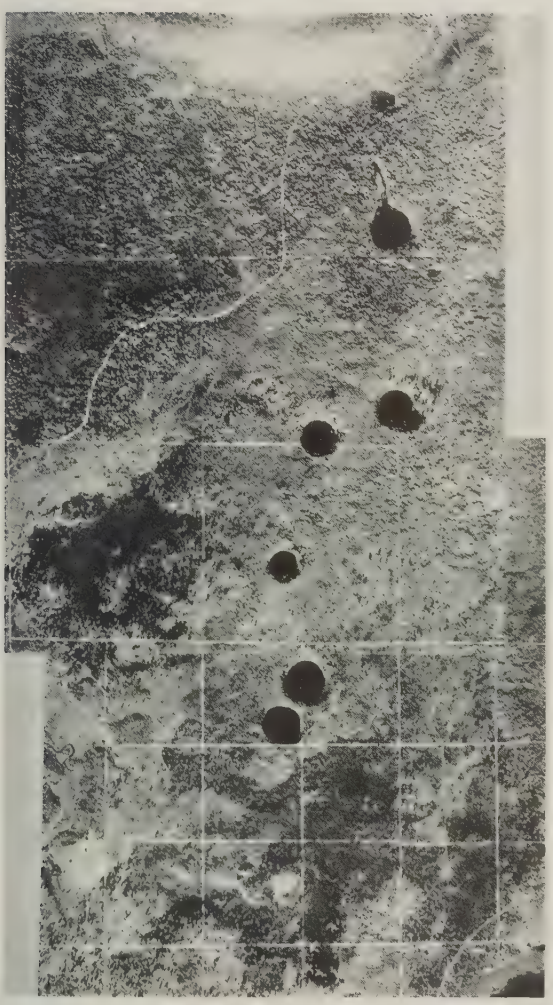


FIG. 1. Aërial photograph of sinkholes near Shoepac Lake, Presque Isle County

FIG. 2. Sunken Lake, Fletcher State Park, Presque Isle County

PLATE LIII



Aërial photograph of sinkhole lakes in Pigeon River state forest, Otsego and Cheboygan counties

ABRUPT DECLINE OF THE WHITTLESEY BEACH AT BIRMINGHAM, MICHIGAN

GEORGE M. STANLEY

THE Whittlesey beach is probably the best possible key to postglacial deformation of the land in southeastern Michigan. It lies out on the lake plain, usually a mile or so from the highest shore line of the ancient lakes in this region, and some sixty feet below it. In most places the beach is a conspicuous ridge of sand and gravel built across valleys and lowlands, and is generally much bolder and more perfectly developed than similar ridges at other levels, since it was built by the waters of a rising lake. In some few places the Whittlesey shore line is marked only by the change in slope of the land, which drops abruptly twenty feet or so into the old lake bottom within a short distance. In general, none of the other shore lines are so marked topographically, except perhaps the highest (Highest Maumee), and certainly none are so easily or so precisely measured for elevation as the Whittlesey beach ridges. Topographic maps cover nearly its whole course from New York to Michigan. The appearance of the beach may be seen in Plate LIV.

The boundaries of the glacial Lake Whittlesey, together with its line of discharge, the events which brought about its rise and decline, and the whole thread of these remarkable deductions are excellently shown and described by Leverett and Taylor.[1] They have also shown how the Whittlesey shore line, northeastward from Birmingham, begins to rise about one foot per mile, whereas southwest of Birmingham it is horizontal. At Birmingham, therefore, is placed one of the hinge lines of the well-known postglacial uplifting movement. Near this hinge line there is a peculiar discrepancy in the elevations of the Whittlesey beach ridges. To demonstrate and, as far as possible, to explain this discrepancy are the objects of this paper. The data were secured in July, August, and October, 1934, during the course of some

[1] *U. S. Geol. Surv., Mon. 53*, pp. 362–385. 1915.

mapping for the Cranbrook Institute of Science of Bloomfield Hills, Michigan.

TABLE I

ELEVATIONS OF WHITTLESEY BEACH

The first seven localities are west of the Birmingham moraine and outside it; the others are east of the moraine or on it.

Elevation of beach	Miles in direction N 25° E	Locality	Township	Section
740.5	0	Crossing Highway U.S.–16	Farmington	28 SE¼
740.5	0.5	Grand River and School Street, Farmington	"	27
741	2.6	Southeast of intersection of Middle Belt and 11-Mile roads	"	24 NW corner
741	4.2	Northeast of intersection of Franklin and Northwestern highways	Southfield	7 SE¼
741.5	5.7	Crossing Telegraph Road just north of 13-Mile Road	"	5 SE¼
742	7.1	Crossing intersection of Lahser and 14-Mile roads	"	4 NE corner
			Bloomfield	34 SW corner
742	7.3	North of 14-Mile Road, one-half mile east of Lahser	Southfield	4 S center
732.5	6.6	500 feet northwest of intersection of 13-Mile and Southfield roads. In several places within one-half mile	Bloomfield	2 SE corner
	7.0		Southfield	11 NE¼
			"	12 NW¼
732.5	7.4	Crossing intersection Greenfield and 13-Mile roads	"	12 NE corner
			Royal Oak	6 SW corner
732	8.2	Crossing Woodward near Parkway Drive	"	6 center
734.5	8.7	Crossing 14-Mile Road, one-half mile east of Woodward	"	6 NE¼
735	9.1	Crossing Grand Trunk Railroad in north end Clover Hill Park Cemetery	Troy	31 SE¼
736	9.9	Crossing East Maple Road almost two miles east of Woodward	"	32 NW¼
737.5	11.0	Crossing Big Beaver Road	"	29 north-central
739	11.7	West of Crooks Road, southwest of cemetery	"	20 NE¼
739	12.2	Crossing Wattles Road, just east of Crooks Road	"	16 SW¼
741	14.4	Southeast of Troy corners, east of Livernois Road	"	10 NW¼

Elevation of beach	Miles in direction N 25° E	Locality	Township	Section
741	16.3	West of Rochester Road	Avon	34 SE¼
745	18.2	South of Ferryview Gravel Company	"	25 NW corner
747.5	22.0	At Grand Trunk Railroad crossing, three miles east of Rochester and one mile north	Shelby	8 NW corner
750	25.3	Just west of Grand Trunk Railroad, one mile north of Washington	Washington	27 NW¼
753	26.2	Just west of Grand Trunk Railroad and highway	"	22 center
751 (?)	34.2	Richmond (measured here by Leverett and Taylor, from a questionable railroad elevation)		
812	86	Threshold of Lake Whittlesey outlet at Ubly		

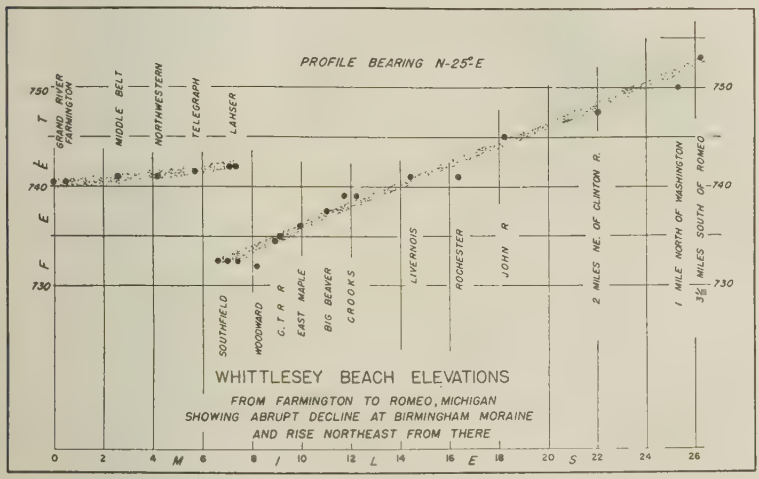
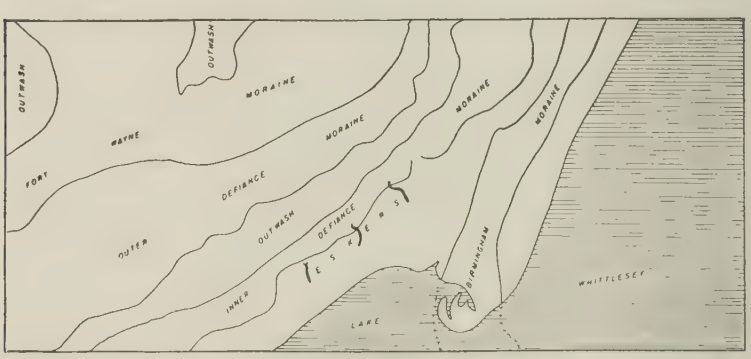


Fig. 23

The elevations of the Whittlesey beach were variously obtained. They are based mostly on the writer's short-distance runs by hand level and stadia rod from such references as railroad and highway profiles and bench marks. In a few cases, when estimates to within a

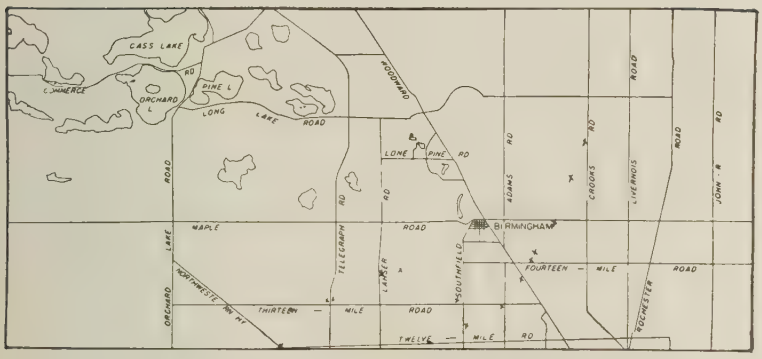
foot could be obtained by the hand level alone, no rod was employed. Probably some of the reference points are not entirely reliable. Errors in leveling may amount to half a foot. Also, in the final act of measuring the beach, variations of a foot or so are always to be found in its gravelly, grassed-over surface. Caution was taken to avoid abnormal heights due to plowing, tree growth, and similar disturbances. In most cases the writer took a series of typical values, and



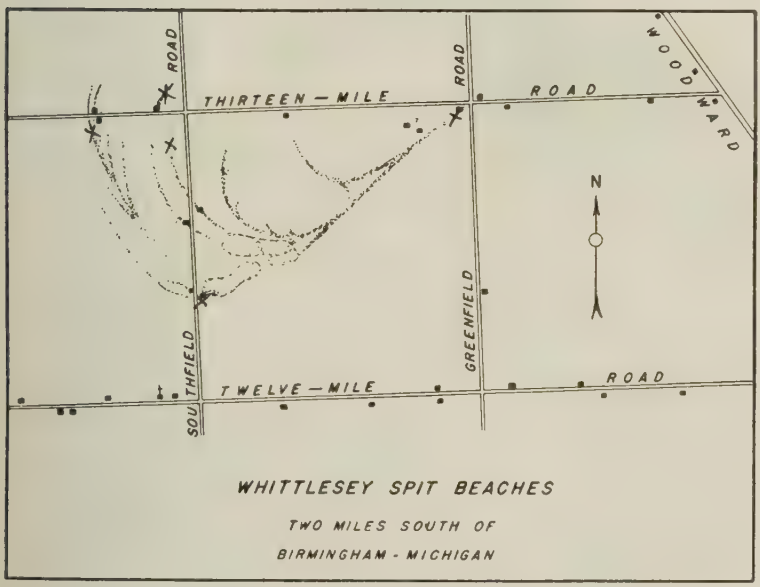
Map 37. Whittlesey shore line and accompanying glacial features in southeastern Oakland County. See also Map 38, which shows the roads in this same area

he presents in the accompanying table the mean of these, to the nearest half-foot. In spite of inaccuracies, it is nevertheless considered that most of the figures are within a foot, or perhaps two feet, of the best possible values.

It is recognized by students of shore forms that gravel ridges may be built at varying heights above or below the water level. Along the shore of a lake such as Lake Whittlesey, however, there must have been a generally uniform maximum height to which the waves could build the stronger beaches. It is this feature of the shore line which the writer has measured. Levels were taken only to the strongest and most conspicuous gravel ridges to be found, and only to their highest typical points. In some places there were secondary ridges a foot or so lower, which have not been referred to in the tabulated results. They are given in the accompanying table and are graphically shown in Figure 23. The locations of most of the points where measurements were made are indicated in Maps 37, 38, and 39.



Map 38. Whittlesey Beach showing points (marked by crosses) where typical elevations were taken



Map 39. Shore ridges showing the points (marked by crosses) where typical elevations were taken

DISCUSSION

Despite the lack of precision in these measurements, there is a regularity in elevation of the Whittlesey beach which bespeaks the general correctness of the values given, with but one notable discrepancy. Beyond the outer (western) side of the Birmingham moraine and to the west the elevation of the beach is consistently between 740 and 742 feet; eastward, between here and Southfield Road, the beach suddenly lapses nearly ten feet in elevation. On the inner (eastern) side of the Birmingham moraine the beach recontinues with a gradual northeastward rise, but does not regain an altitude of 742 feet until some nine miles farther to the northeast. This abrupt lapse in elevation is shown conspicuously in Figure 23. It is also perfectly apparent from the United States Geological Survey contour maps of the Pontiac and Rochester quadrangles.

In seeking the cause of this discrepancy in level of the beaches we may first consider the possibility that it has existed from the beginning, and that the beaches at Southfield Road were formed at a level some ten feet below those at Lahser Road (two miles to the northwest), in which case the land in the vicinity has been stable. At Southfield Road the ridges constitute a magnificent series of recurved spits, as may be seen in Map 39. And since many spits are known to have been built and prolonged beneath lake level, it might be supposed that these ridges were made subaqueously in Lake Whittlesey, whereas the beaches to the west were built above the water; and that this condition accounts for the difference in level between them.

However, a closer knowledge of conditions here renders this view untenable. Anomalously low elevations, as may be seen from Figure 23, characterize the Whittlesey beach from Southfield Road for nine miles to the northeast to near Livernois Road. The writer is not aware of any subaqueous spit which has attained such magnitude in a similar environment. Moreover, at Greenfield and Thirteen-Mile roads, only a mile or so from the terminal part of the spit, the beach is banked against the till of the Birmingham moraine in such a way as to show quite positively that it was formed marginal to the lake and not below it. A similar condition exists where the Whittlesey beach is crossed by East Maple Road. And along the edge of the lake we might reasonably expect the beaches to be developed at approximately the same elevations as in similar situations farther west.

Moreover, the writer is inclined to regard the spits near Southfield Road also as having been constructed to a level above the water surface of Lake Whittlesey, and not below. Southwest from Greenfield Road many spit ridges segregate from the principal beach. Where undisturbed for gravel, the most prominent of these ridges, if not all, maintain level, even crests right up to their terminal points. Elevations taken on several of them, at many places between Southfield Road and the ends of the spits, all fall around 732 or 732.5 feet, which is the elevation of the beach at Greenfield Road. At the termination of each spit there is a drop-off, very abrupt and amounting to eight or ten feet in some places. Clearly these surprisingly low elevations of the Whittlesey ridges at Southfield Road are not due to a gradual lowering in level of the spits where they protruded out into the former lake to pass beneath its water level. The writer regards them all as having been formed slightly above water level, like many spits or bars in the Great Lakes today.[2]

It seems possible that the anomaly under discussion is the result of wave work at different levels of Lake Whittlesey, which was probably subject to seasonal fluctuations. However, this single, large change in elevation seems too much out of proportion to the irregularities elsewhere to suit such an explanation. Although satisfactory proof is perhaps lacking, the writer regards these data as very suggestive of vertical movement of the land.

CONCLUSIONS

There appear to be two possible views of the nature of this vertical movement.

1. As noted by Leverett and Taylor,[3] the hinge line for the post-Whittlesey uplifting is at Birmingham, Michigan. It might be more than a coincidence that vertical faulting should take place at one of the hinges of uplift. If this is so, the throw would be in a direction opposed to the general movement of uplift. At the time of writing data are not sufficient to enable one to say whether "structures" exist in the underlying bedrock at this hinge.

2. The second view is less plausible than the first, but is mentioned because of two rather striking occurrences elsewhere. Leverett

[2] See *U. S. Geol. Surv., Mon. 53*, Plate 29C.
[3] *Op. cit.*, p. 381.

and Taylor note that in different localities Whittlesey and Maumee shore lines seem to lapse in elevation where passing eastward over the water-laid Defiance moraine.[4]

Although these observations are based on meager data, they suggest relations of the beaches to a former ice boundary exactly similar to that shown by the Whittlesey beaches to the Birmingham moraine, as here described. If the location of the postglacial subsidence is determined by moraines, with movement restricted perhaps to surficial deposits, as seems possible from the occurrences mentioned, then an explanation becomes exceedingly difficult.

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[4] *Op. cit.*, pp. 346, 381.

FIG. 1. View looking west at the Whittlesey beach from out in the lake plain. The barn and the cemetery (at the extreme right) are situated on the beach which is on the far side of Crooks Road. The location is shown on Maps 37 and 38

FIG. 2. View northeast along the lakeward side or fore slope of the Whittlesey beach on the west side of Crooks Road. The house is on the summit of the beach, which slopes off in back; in Figure 1 it is concealed by the heavy clump of trees near the barn

THE FOUR AND ONE-HALF PER CENT DUTY, 1663–84

KARL H. REICHENBACH

THE restoration of the Stuarts in 1660 gave rise to the problem of a definite settlement of the status of Barbados and the Leeward Islands in the British Empire. Should the Cromwellian system of more or less direct control be retained or should the old proprietary government, as existing under Charles I, be restored? In either solution, what was the Crown to derive from the islands and what were the details of the arrangement to be? The $4\frac{1}{2}$ per cent export duty was an integral part of the settlement and may be properly understood only in that connection.

Naturally, in a question so vital as the future status of Barbados in the British Empire, factions within the island sprang up. Lord Francis Willoughby, former governor under the proprietary régime and holder of an unexpired lease under the original Carlisle patent, led the group favoring a return to the status of Charles I's time. He was opposed by the faction favoring more direct royal control, under the leadership of Colonel Thomas Modiford, who had been governor during the parliamentary régime. Modiford was supported by those planters who had found proprietary control irksome and by an intelligent sentiment close to the king himself, which felt that the Crown's interests would be better served by royal government. There was an additional complication in the questionable legality of the Carlisle patent, which had been declared invalid by decision of the attorney-general.[1]

Jonathan Colleton and Thomas Kendall, two men of the Modiford faction, went so far in their zeal for royal control as to offer the Crown an export duty of 4 per cent, although unauthorized to do so.[2] The president and the council repudiated this offer in July,

[1] Harlow, V. T., *A History of Barbadoes, 1625–35* (Oxford, 1926), p. 131. See Williamson, J. A., *The Caribbee Islands under the Proprietary Patents* (London, 1926), for a discussion of the complicated question of proprietary claims.

[2] *Calendar of State Papers, Colonial, 1661–68*, Nos. 40, 60. (This title is hereafter abbreviated *C. S. P., Col.*)

1661, petitioning the king for retention of the old 2 and 4 per cent duty.[3] In July, 1662, Waldrond, an influential Barbados planter, attempted to secure the consent of the assembly of the island to the return of the proprietary government, urging in place of the Modiford offer the voting of a large sum to the king and a petition against the proposed 4 per cent levy. Although favoring the financial measure, the assembly withheld its support because it was definitely opposed to proprietary government.[4]

Charles II finally stepped in and put an end to the dispute. Deterred by the difficulty of settling conflicting proprietary claims and attracted by the possibility of revenue he decided to take the Carlisle grant under the royal wing and sent over Willoughby as royal governor. Willoughby was instructed to secure some form of revenue in lieu of the former proprietary dues.[5] With some difficulty, he secured the passage of the $4\frac{1}{2}$ per cent export duty in Barbados in September, 1663. The several Leeward Islands passed similar acts in 1664.

With the definite decision of the Crown against the reëstablishment of the old proprietary patent, the planters of Barbados and the Leeward Islands were disturbed as to the future status of their landholdings. The claims of many of them were vague, and some perhaps could have produced none at all. In their concern the council and the assembly of Barbados voted an address for presentation to the king, which was to contain, among other things, a request for an act of Parliament to secure the tenures in Barbados as they then stood, in free and common socage of the king.[6]

In June, 1663, the future disposal of revenue from the Caribbee Islands was made by an order in council. The arrangement provided "one moiety to the use of Lord Willoughby during the remainder of the lease by which the same is devised to him and afterwards towards the support of the government." The rest was to be disposed of in various ways. The Earl of Marlborough was to receive £300 a year, which annuity was to pass to William Ley on the Earl's death. The Earl of Kinnoul, heir of Carlisle, was to receive £500 per year until the creditors of Carlisle were paid. Then he and his

[3] *C. S. P., Col., 1661–68*, Nos. 127, 129.
[4] Harlow, *op. cit.*, p. 137.
[5] Beer, G. L., *The Old Colonial System* (New York, 1912), I, Part I: 178–179.
[6] *C. S. P., Col., 1661–68*, No. 392.

heirs were to receive £1,000 in perpetuity. The claims of the creditors were to be settled at two thirds of the original figure. Finally, the Crown was to receive the remainder of the second moiety.[7]

According to Willoughby's own account, in a letter to the king dated 10th September, 1663, we learn that he "arrived in Barbadoes 10th August and laid his Majesty's commands before the assembly in being, to avoid the delay of calling a new one . . . . They have agreed to levy a custom of $4\frac{1}{2}\%$ on all commodities grown in the island and hope it may hereafter be advanced if his Majesty would grant them some privileges which the Act of Navigation doth debar them of." [8] From other accounts it is apparent that the act was passed only after three weeks of weary and acrimonious debate in the assembly,[9] and a certain amount of threatening, coaxing, and deceit on the part of the governor.[10] Opposition to the legislation was very great, and one of the leaders in the party of obstruction was subsequently arrested and sent to England.[11]

The act itself was destined to be productive of so many disputes that it is well to consider it carefully. It was far-reaching in its provisions and implications and may be viewed in a sense as legislative sanction by the representatives of the planters, of the arrangement made by the king in England. It not only imposed the $4\frac{1}{2}$ per cent duty, but also abolished proprietary dues and made secure the land tenures of the inhabitants.

There is a plain statement of the purpose of the levy in terms which cannot be misconstrued: ". . . and for as much as nothing conduceth more to the peace and prosperity of any place . . . than that the public revenue thereof, may be in some measure proportioned to the charges and expenses; and also weighing the great charges that there must be of necessity in the maintaining the honor and dignity of his majesty's authority; the public meetings of the sessions; the often attendance of the council; the reparations of the forts; the building a sessions' house and a prison; and all other public charges incumbent on the government; the assembly does in consideration thereof, give unto his majesty, his heirs and suc-

[7] *Ibid.*, No. 482.
[8] *Ibid.*, No. 561.
[9] Beer, *op. cit.*, pp. 179–180, note.
[10] *C. S. P., Col., 1661–68*, Nos. 544, 1679.
[11] Schomburgk, Sir R. H., *History of Barbadoes* (London, 1848), p. 289; Poyer, John, *History of Barbadoes* (London, 1808), pp. 175–176.

cessors forever; . . . and we humbly pray that it be enacted . . . that an impost or custom . . . be raised upon all dead commodities of the growth or produce of this island that shall be shipped off the same shall be paid to our sovereign lord the king . . . four and one-half in specie for every five score." The penalty for evasion was fixed at forfeiture of goods, one half going to the king and the other to the informer. Produce of land owned by the governor and certain creditors of Carlisle were specifically exempted from payment.

Other clauses secured land tenures in accordance with the existing practice in the island, abolished levies such as the forty pounds of cotton per head, and canceled all rents and arrears thereof. "The inhabitants of this island have and hold their several plantations to them and their heirs forever, in free and common socage, yielding and paying for them at the feast of St. Michael every year; if the same be demanded, an ear of Indian corn to his majesty, his heirs and successors forever." This was to constitute a full discharge of all previous rents and services.[12]

Although the terms of the act of 1663 seem clear enough when they are examined carefully, they were soon interpreted in conflicting senses by the home government and the colonists. The usual British interpretation was that the duty had been granted to the Crown in return for confirmation of existing land titles and abolition of irksome proprietary dues.[13] Naturally the revenue could, from such a viewpoint, be disposed of as the Crown saw fit. Ordinary expenses of government, with the exception of the governor's salary, which customarily came out of the $4\frac{1}{2}$ per cent, should be met by other taxes.[14] The planters, on the other hand, maintained that the entire revenue should be used solely for public purposes, particularly those enumerated in the act. Only in case of a deficit were new taxes to be imposed. To this interpretation Barbados clung tenaciously for 175 years, until the act was repealed.

Beer explains the conflict by declaring the law ambiguous which was due to the opposite, and not clearly expressed, aims of Willoughby

[12] *Acts Passed in the Island of Barbadoes, 1643–1762*, ed. R. Hall and R. Hall, Jr. (London 1764), Act of 12th September, 1663. The act received royal approval, with the exception of the exemption clause. No exemptions at all were allowed. — *C. S. P., Col., 1661–68*, No. 981.

[13] *C. S. P., Col., 1675–76*, No. 155.

[14] Beer, *op. cit.*, p. 182.

and the assembly.[15] Upon examination, however, the provisions of the act seem clear and definite enough. Rather should the controversy be explained by the inconsistency between the order in council of June, 1663, already mentioned, and the arrangement made by the assembly in Barbados. If in framing the act the latter was aware of the existence of the order in council it ignored it, while the home government in its approbation failed to reconcile the divergent provisions of the two documents.

In the Leeward Islands we find no question of interpretation or policy arising. The several assemblies of St. Kitts, Nevis, Montserrat, and Antigua in the course of 1664 passed bills unequivocally granting the export duty of $4\frac{1}{2}$ per cent in return for confirmation of land titles and abolition of proprietary dues.[16] True, a petition from Nevis did request that forts and troops be maintained out of the fund, but there were no legal grounds to warrant expectation of acquiescence by the home government.[17]

From 1663 to 1670, the year of the first farm, the levy was collected by the government, part of the time under the supervision of the governor of Barbados and part of the time under the supervision of Sir Tobias Bridge, commander of the West Indian regiment.

It was unfortunate for Barbados that the period after the voting of the $4\frac{1}{2}$ per cent was such a troubled one. In the summer of 1664 the English seized New Amsterdam, and the strained relations with the Dutch finally developed into open war by February, 1665. In 1666 Holland was joined by France. War with these two nations meant interruption of the West Indian trade, fighting in the islands, and increased expenses for both the colonial and the home governments. Before the levying of the new duty had had an opportunity to develop and function in a normal way, the empire was plunged into war, which brought an abnormal strain on administrative and financial branches of the government. Add to this the impecuniosity of Charles II, due partly to his own extravagance and partly to the parsimony of Parliament, and we have perhaps found the key to what eventually developed into the maladministration of the $4\frac{1}{2}$ per cent duty.

[15] *Ibid.*

[16] Higham, C., *Development of the Leeward Islands under the Restoration* (Cambridge, 1921), p. 24; Beer, *op. cit.*, pp. 180, 182.

[17] *C. S. P., Col., 1661–68*, No. 732.

A certain amount of the proceeds was used during this period for defense against the Dutch and the French. The expenditure of £1,000 was authorized in June, 1664, to finish the great fort in Jamaica.[18] Nevis asked that in its own territory forts and guards be maintained out of the 4½ per cent.[19] Governor Willoughby desired to use the revenue from Barbados for forts and garrisons, in spite of the protests of the creditors of the Earl of Carlisle,[20] and there seems to be some evidence that he did so.[21] But even the entire revenue from this source was hopelessly inadequate to meet Willoughby's expenditures of £100,000 during his administration.[22]

The lack of funds involved the governor in a quarrel with the Barbados assembly in 1665 and 1666. A recalcitrant assembly was dissolved in 1665,[23] and a new one was called the next year in accordance with the king's instructions, for the consideration of the defense of the island. The assembly refused to grant additional revenue, declaring that the expense of protection should be borne by the king out of the 4½ per cent, as intended by the act of 1663. Although the governor would not accept such an interpretation, the assembly stubbornly clung to its point, agreeing only to concede a loan of 500,000 pounds of sugar, to be secured by the future revenue from the levy, adding, gratuitously, that all public charges should come out of the 4½ per cent, which it considered "all that could be ever meant to be given or asked in any time by way of aid or otherwise." [24] In spite of their protests the Barbadians, who probably overestimated the proceeds of the 4½ per cent, which at this time did not exceed £6,000 annually,[25] were compelled to raise additional funds for defense of the island.[26] This is the first instance of the assertion of the point of view maintained by Barbados down to 1715.

The Treaty of Breda (1667) brought relief to Barbados and the

[18] *C. S. P., Col., 1661–68*, No. 752.
[19] *Ibid.*, No. 737.
[20] *Ibid.*, Nos. 1017, 1018.
[21] Beer, *op. cit.*, pp. 182, 184. Harlow (*op. cit.*, pp. 156–157) states that Willoughby was not permitted to touch the 4½ per cent for purposes of defense. It seems likely, however, that Willoughby did use proceeds for that purpose.
[22] Harlow, *op. cit.*, p. 188.
[23] *Ibid.*, pp. 156–157.
[24] Harlow, *op. cit.*, p. 160; *C. S. P. Col., 1661–68*, No. 1121.
[25] *C. S. P., Col., 1661–68*, Nos. 1151, 1632, 1633.
[26] *Ibid.*, Nos. 1565, 1576; Harlow, *op. cit.*, pp. 161–164.

Leeward Islands, but the regiment of Sir Tobias Bridge, stationed in the West Indies, was henceforth to be maintained out of the 4½ per cent.[27] Governor William Willoughby, nephew of and successor to Sir Francis Willoughby, complained in a report to the Privy Council in 1668 that even for this purpose the revenue was insufficient and that he was compelled to support himself from his own estates and credit.[28]

In 1667 the assembly of Barbados petitioned the home authorities against restrictions imposed on trade of the island. Free trade with Guinea for Negroes and with Scotland for servants was requested. It was also proposed that the islanders be permitted to export goods anywhere, provided it was done in English bottoms after payment of the regular English customs in Barbados. This was a protest against the restrictions of the navigation acts, a protest which was to continue for a long time and which was closely associated with the 4½ per cent in the minds of the Barbadians.

To this protest was added, in July, 1668, a request for the abolition of the 4½ per cent made by merchants and planters of Barbados resident in London, the first of a number to follow.[29] The king called a conference of a committee of the Privy Council with London merchants to consider the situation. The merchants and the planters recommended that the free trade in Negroes and Scottish servants be permitted. To this they added the suggestion that "the duty of 4½% . . . which is a great burden and grievance may be removed or moderated and that what duty his Majesty shall think fit to continue may be collected at . . . the customs house here. Whereby the charge and vexation of collecting it in Barbados may be removed. . . ." [30]

The first recorded formal protest from the government of Barbados appeared in a petition to the king dated 3rd August, 1668. The duty was represented as a heavy burden imposed by an assembly illegally convened, and the king was urged to accept a lump sum for its commutation. If this was not acceptable, the duty should be collected in England, by "some reasonable rate on sugars." [31]

The alternative request for a duty on sugar levied in England was made no doubt with the intention of placing all sugars imported

[27] Beer, *op. cit.*, pp. 184–185.
[28] *C. S. P., Col., 1661–68*, No. 1836.
[29] *Ibid.*, No. 1739.
[30] *Ibid.*, No. 1769; Harlow, *op. cit.*, pp. 194–195.
[31] *C. S. P., Col.*, 1661–68, No. 1816.

into that country on the same basis with those from Barbados and the Leeward Islands. As it was, these places could not compete in the English market with others which were free from the 4½ per cent levy. What the petitioners asked was in a sense only justice, since they were required by law to take their main product to England.

The king had already seen fit to order the disbanding of the West Indian regiment after it had been paid off out of the 4½ per cent,[32] but this order was countermanded two months later, July, 1668, because of the delay in the French evacuation of St. Kitts. At the same time Bridge was ordered to take over the administration of the duty and to maintain the troops out of the returns.[33] Willoughby, in a letter to the Privy Council which evinced his satisfaction at being relieved of the burden of responsibility, pointed out that the cost of the regiment would absorb more than the king's moiety, leaving nothing for the other expenses, namely, the charges for the government of Barbados and for the debts contracted in its defense in the late war.[34]

As Willoughby predicted, the moiety of the 4½ per cent set aside for these purposes was insufficient. Complaints against the alleged misapplication of the revenue and a renewed suggestion for a duty on sugar levied in England were made in 1669.[35] In April of the same year Bridge reported to the Privy Council that the revenue produced in the previous eight and one-half months had sufficed for only four months' half-pay to the officers, two months' pay to the soldiers, and quarters for two months. Additional expenses met were for some provisions for an expedition under Colonel Stapleton and, of course, the salaries of the collectors of the duty.[36]

The administration of Bridge, as well as that under the supervision of the governors of Barbados, had been eminently unsatisfactory. Bridge had met hostility from the planters [37] and actual opposition in the collection from the deputy treasurer.[38]

[32] *Acts of the Privy Council, Colonial*, Vol. I, No. 775. (This title is hereafter abbreviated *Acts of P. C., Col.*)

[33] *Ibid.*, No. 792.

[34] *C. S. P., Col., 1661–68*, No. 1854.

[35] Beer, *op. cit.*, p. 186; *C. S. P., Col., 1699*, Addenda, No. 1113. The suggested duty was one of 12*d.* on muscovados and 2*s.* 6*d.* on white sugar per cwt.

[36] *C. S. P., Col., 1661–68*, No. 1761; *ibid., 1669–74*, No. 49.

[37] Harlow, *op. cit.*, p. 194.

[38] *Acts of P. C., Col.*, Vol. I, No. 832.

The complaints and difficulties incident to the administration of the duty from 1663 to 1670 are typical of the whole story down to 1715. The planters, insisting on their interpretation of the act of 1663, protested repeatedly against the misapplication of the funds, and in their own minds considered the restrictions of the navigation acts in conjunction with the 4½ per cent an injustice of the imperial system singling them out as the sole object among all the colonies. Either alone might be supportable, but the combination was too much.

The failure of government administration of the 4½ per cent, apparent by 1669, led the Privy Council to authorize the farming of the duty. The obvious advantage of receiving a fixed sum each year, in spite of the vicissitudes of the collection in the islands, was no doubt attractive to Charles and his advisors. Accordingly, on 22nd December, 1669, the 4½ per cent in Barbados was farmed to Robert Spencer, Sir Charles Wheler, George Marsh, and Edward Cranfield for a period of seven years at an annual payment of £7,000.[39] The king was to use the revenue to support the troops remaining in Barbados, make up their arrears, and pay legitimate claims of those who had lost ships and goods in the late war.

The planters saw in this new arrangement a definite repudiation of the act of 1663. True, the 4½ per cent had been in the past diverted from the prescribed channels, but in 1669 it was impossible, in ignoring the needs of the Barbados government, to plead the exigencies of war. Governor Willoughby pointed out the dissatisfaction sure to arise from the new arrangement, maintaining that the former one was better, providing "at least enough to preserve Sir Tobias Bridge's regiment from starving."[40] The officers of Bridge's regiment, fearful for their salaries now that the duty was payable at Westminster, asked that provision therefore be made out of the regular establishment of the treasury.[41]

Feeling in Barbados against the farm ran high, according to Christopher Codrington, deputy governor in Willoughby's absence. The assembly refused to quarter the troops any longer and refused to vote the governor any money as a personal gift, although the

[39] *Ibid.*, No. 881. It appears that there was at the same time an offer of £7,500 for the farm. See *ibid.*, No. 878.

[40] *C. S. P., Col., 1669–74*, No. 235.

[41] *Acts of P. C., Col.*, Vol. I, No. 895. The arrears in pay of the regiment at this time totaled 500,000 pounds of sugar.

previous year it had given him 200,000 pounds of sugar.[42] In January, 1671, the question of quartering troops was still a problem in managing the recalcitrant assembly.[43]

About this time a commission was formed in London of gentlemen planters and merchants to represent the interests of Barbados in England. In its personnel were such men as Sir Peter Colleton, Sir Paul Painter, and Ferdinando Gorges. Protests of the islanders were transmitted to the government through this body. In December, 1671, it presented a protest of the assembly of Barbados against the famous proposal to levy a duty of $2\frac{1}{2}$ farthings on sugar in England and against the refusal of the commissioners and farmers to spend any of the $4\frac{1}{2}$ per cent for government of the island.[44]

These representations seem to have had some effect, as is indicated by the instructions to William Willoughby, issued in 1672. Back debts due out of the $4\frac{1}{2}$ per cent, totaling £37,555, were enumerated. In the future the Earl of Kinnoul was to receive certain specified annuities. Willoughby was to meet both these charges from the $4\frac{1}{2}$ per cent, but was to treat with the assembly for the abolition of the duty, as it "seems very burdensome," and to substitute a new form of revenue which was to pay these charges and provide £4,000–£5,000 a year for the support of the government. Meanwhile the farmers were to turn over £800 quarterly for current administration in Barbados.[45] It seems that Charles and his committee of trade and plantations were making an honest effort to administer the duty in an equitable fashion and to meet just claims and obligations out of it.[46]

The proposal to substitute another form of revenue for the $4\frac{1}{2}$ per cent came to naught,[47] but the assembly did agree in 1673 that for the duration of the Dutch war the king might dispose of the revenue as he saw fit.[48]

In 1676 Governor Atkins brought on his head the wrath of the

[42] *C. S. P., Col., 1669–74*, No. 171. Sugar at this time in Barbados was worth 12*s.* 6*d.* per cwt. [43] *Ibid.*, No. 388.

[44] Harlow, *op. cit.*, pp. 203–205; *C. S. P., Col., 1667–74*, Nos. 671, 674.

[45] *C. S. P., Col., 1669–74*, No. 845.

[46] *Ibid.*, No. 545; *Acts of P. C., Col.*, Vol. I, No. 900. Oldmixon states that Charles was assigning pensions from the $4\frac{1}{2}$ per cent to favorites and others, but we can find no evidence to substantiate this charge. — J. Oldmixon, *The British Empire in America* (London, 1708), II: 28. [47] *C. S. P., Col., 1669–74*, No. 1027.

[48] *Ibid.*, No. 1098. Protests from planters bearing the old grievances continued to appear during this year, however.

lords of trade and plantations by daring to transmit a protest from the assembly of Barbados against the enumeration clause of the Navigation Act of 1660.[49] He was also reproved for criticizing the Royal African Company and the administration of the $4\frac{1}{2}$ per cent.

The hostility of the islands to the duty at this time was enlivened by the controversy over the weighing of the sugar casks by the collectors of the customs,[50] and by the act of the assembly of Barbados, passed in 1675 and again in 1679, providing for the refund of the $4\frac{1}{2}$ per cent paid on cargoes subsequently lost at sea. The practice of weighing stopped in Barbados only when the interests of the farmers were safeguarded by an act of the assembly definitely establishing by law the dimensions of the various casks.[51] The Privy Council would not permit the statutes providing for refund of the $4\frac{1}{2}$ per cent and persuaded the king to annul them.[52]

The farm of 1670–77 had proved definitely unprofitable to the farmers and unsatisfactory to both the islanders and the home authorities. The duty return was not sufficient to produce the amount of £7,700 per year, including in the reckoning the rent of the Leeward Islands' farm.[53] The same is true of the second farm, 1677–84, even though the rent was reduced to £5,300 per year, for both the Leeward Islands and Barbados.[54] In the final reckoning in 1684, £53,900 was due the government from both farms. Of this amount, only £21,000 had actually been paid in. The treasury claimed £10,481 of the balance after allowing certain deductions to the farmers. Even from this sum the latter requested a further remittance of £4,800.[55]

Faced again, in 1684, with the failure in the collection and administration by the farm, the treasury decided to assume the management of the troublesome duty and continued to do so thenceforth. Unfortunately, the mere change in administration did not and could not solve the questions at issue. The fundamental controversies and differences disappeared only with the repeal of the navigation acts and the abolition of the $4\frac{1}{2}$ per cent duty itself in 1837.

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[49] *C. S. P., Col., 1675–76*, Nos. 811, 812, 1116.

[50] For the controversy over the casks see *C. S. P., Col., 1669–74*, No. 549; *ibid., 1675–76*, Nos. 714, 1096; *ibid., 1685–88*, No. 624; Beer, *op. cit.*, I: 188–189.

[51] *Acts of Barbadoes*. Act of 15th April, 1675.

[52] *Acts of P. C., Col.*, Vol. I, No. 1298. [53] *C. S. P., Col., 1669–74*, No. 1029.

[54] Beer, *op. cit.*, p. 188. [55] *Ibid.*

THE INFLUENCE OF THE DREYFUS AFFAIR ON THE POLITICAL DEVELOPMENT OF FRANCE

RUDOLPH A. WINNACKER

I

THE Dreyfus Affair is usually considered a turning point in the history of the Third French Republic. In the opinion of many the success of the Dreyfusards marks the final victory of the ideals of the French Revolution over those of the *Ancien Régime*.[1] Such an important result seems to indicate that a political revolution took place in France during the years 1898–99. The facts, however, do not bear out this conjecture. Neither an electoral victory nor a fundamental realignment of parties made the success of the Dreyfusards possible. The Dreyfus Affair merely speeded up a movement in French politics which had been gathering force since the beginning of the last decade of the nineteenth century.

The election of 1893 marked the first great republican victory since the establishment of the Republic.[2] Only seventy-eight Monarchists and Boulangists were elected as opposed to five hundred and three supporters of the republican form of government. This large majority, however, was not homogeneous. After a period of trial and error which furnished five ministries between 1893 and 1895, it split into two parts: one in favor of a conservative republic, the other supporting a radical policy. The latter was by far the

[1] Recouly, R., *La Troisième République* (Paris, 1927), p. 176; Thibaudet, A., *La République des professeurs* (Paris, 1927), p. 30; Clauss, M., *Das politische Frankreich vor dem Kriege* (Karlsruhe, 1928), p. 16; Soltau, R., *French Political Thought in the Nineteenth Century* (New Haven, 1931), pp. 346–359.

[2] The election of 1871 was a Monarchist victory; those of 1876 and 1877 still gave over one third of the votes to the Monarchists. The election of 1881 appeared as a republican victory only because of the abstentions of the voters of the Right, an impression which was quickly corrected in 1885. In 1889 the republicans were merely able to hold their own against the combined forces of Boulangism.

weaker. It was able to control the government for only six months, from November, 1895, to April, 1896, when it gave way to an alliance of the conservative forces under Méline, who kept his majority together until after the elections of 1898. The composition and the policies of these two political combinations must be explained, for they represent the divisions which are usually considered the result of the Dreyfus Affair.

The main strength of the conservative forces came from the republican group, known as Progressist.[3] The deputies of this group were satisfied with the Republic as Thiers had established it, a monarchy without a king, an individualistic, *antiétatiste* régime of the upper classes, opposed to social legislation. *Ni révolution, ni réaction* was their slogan. To safeguard the conservative Republic they worked for the conversion of Monarchists and Catholics to republicanism by a policy of *apaisement*. They hoped that with the help of these *ralliés* a conservative majority could be established which would liberate them from the annoying alliance with the Radicals. Though some sixty members of the group had their doubts about the sincerity of the new converts, most of them followed Méline from 1896 to 1898, when this prime minister put into effect the conservative policy called the *esprit nouveau*.[4]

The opposing faction was known as the Union of the Lefts, composed of the Radical, the Radical-Socialist, and the Socialist groups. The Radicals traced their political pedigree back to Gambetta's program of Belleville, proposed in 1869, but as realists they saw the impossibility of gathering a majority in the near future to realize such reforms as the separation of State and churches, an income tax, the election of judges and other civil servants. Consequently they were eager to coöperate with the Progressists whenever possible in dividing the spoils of office. The Radical-Socialists, on the other hand, acted as if they believed in the Belleville program. They refused to compromise with the Progressists and considered themselves the spiritual heirs of the Jacobins of 1792, claiming to be the prophets of the democratic, laïcal, and fraternal republic of the fu-

[3] In order to avoid confusion the name Progressist will be used throughout the text to designate these conservative republicans, though it was not adopted by the group until 1898.

[4] An excellent summary of the two tendencies within the Progressist group is given by J. Méline, "Les Partis dans la République," *Revue politique et parlementaire*, Vol. 23, January 10, 1900.

ture.[5] The third group in this union consisted of various factions sailing under the flag of socialism. Temporarily discouraged by the fate of the Commune of 1871, these champions of the proletariat had gathered by 1890 a new feeling of hope and courage, based on the gospel of Marx and the memories of Babeuf, Louis Blanc, and Blanqui.[6]

The election of 1898 was to test the strength of these two alliances. Since the Dreyfus Affair was still in its early stages and played only a minor part,[7] the great issue was between conservatism and radicalism. The result, however, was far from decisive. Neither the Progressists nor the Union of the Lefts could muster a majority in the Chamber of Deputies.[8] The importance of the election, therefore, does not appear in the actual election returns. It is to be sought in the attitude of the two groups at the extreme right and left of parliament. In the first place, the hostility of some Monarchists toward their recent allies, the Progressists, had resulted in the defeat of two of Méline's ministers and nearly twenty of his followers.[9] Secondly, the Socialists, by tacitly accepting Millerand's famous minimum program of St. Mandé, had lost the stigma of revolutionism and taken their place in the parliamentary republic as a party of reform.[10] Thus the foundations had been laid for a future alliance between the deputies of the left wing of the Progressist group and the Union of the Lefts. The former, who had been undecided whether the Monarchists or the Socialists presented the greater peril to the Republic, now had grave doubts regarding Mé-

[5] On the evolution and spirit of the Radical party see Maurice, G., *Le Parti Radical* (Paris, 1929); Alain, *Éléments d'une doctrine radicale* (Paris, 1925); Herriot, E., Seignobos, Ch., and others, *La Politique républiquaine* (Paris, 1924).

[6] For the history of Socialism see especially *Histoire des partis socialistes en France*, edited by A. Zévaès, 12 vols. (Paris, 1911–23); Weil, G., *Histoire du mouvement social en France, 1852–1924* (Paris, 1924); Louis, P., *Histoire du socialisme en France* (Paris, 1925).

[7] France was still overwhelmingly anti-Dreyfusard in June, 1898, and consequently the Nationalists lacked the necessary opposition for a great electoral campaign.

[8] The Progressists and their conservative allies could count on about 357 votes in both the last and the new legislatures. However, future events showed that the vacillating votes of the left-wing Progressists had increased from 63 to 86. These results are derived from the author's own statistics based on the votes of the deputies in the Chamber.

[9] Lachapelle, G., *Le Ministère Méline* (Paris, 1928), pp. 176–181.

[10] Daniel, A., *L'Année politique*, 1896 (Paris, 1897), pp. 205–210; Orry, A., *Les Socialistes indépendants* (Paris, 1911), pp. 18–32.

line's *esprit nouveau* policy and looked upon the Socialists as less dangerous to the bourgeoisie than before.

This result of the election became evident as soon as Méline faced the new Chamber. On June 14, 1898, the deputies approved the general policy followed by Méline during the past two years by a majority of twenty-three, but at the same time passed a resolution calling for a cabinet "supported exclusively by republicans." Since the majority on the first vote had included over eighty Monarchists and Ralliés, Méline was forced to resign. All attempts to create a cabinet based on the coöperation of Radicals and Progressists failed.[11] The animosities created during the electoral campaign were too deep to be forgotten immediately. Something approaching the two-party system seemed to be in formation in France, as the Progressist Méline was succeeded by a cabinet of the Union of the Lefts, headed by Brisson. This change in the government of France was made possible only by the vacillations of nearly forty deputies of the left wing of the Progressist group who first had supported Méline, but who later cast their lot with the groups of the left.[12]

It appears from these events that even before the Dreyfus Affair threw France into turmoil the French parliament was divided into two hostile camps. Therefore, the *bloc* of the Lefts ought not to be considered a product of this crisis, since a similar political alliance was in existence during the years from 1895 to 1898. Likewise, the Progressist group, which practically disintegrated during the critical days of 1899, had in fact started its decline immediately after the elections of the previous year. In other words, the final political result of the Dreyfus Affair was not the break-up of the old political alignments, but the reënforcement of existing divisions.

II

When Brisson came to power very few people doubted the guilt of Dreyfus. The prime minister himself had promised the suppression of the Dreyfusard agitation. The discovery of the *faux Henry*, however, and the consequent suicide of Colonel Henry on August 31, 1898, prevented the execution of this program. Overnight

[11] On the efforts of Ribot, Sarrien, and Peytral to form a concentration cabinet see *Le Temps*, June 19, 22, 26, 27, 1898.

[12] All statements in regard to votes are derived from the author's analysis of these votes as given in the *Journal officiel.*

the Dreyfusards grew from an insignificant group of idealists into a great national party. Jews, Protestants, anticlericals, intellectuals, hostile to the unreasoning faith and blind obedience as practiced by many in the Catholic Church, coöperated with sincere republicans, afraid of the growing influence of the military power over the civil government. In their opinion the fact that one document offered as proof of the guilt of their client had been fabricated threw a doubt on the authenticity of all the other documents. Consequently a revision of the Dreyfus case was necessary. Opposed to this revision were most of the patriotic elements in the nation: army officers defending the honor of their profession and of the military courts, the Catholic clergy and its devoted flocks trying to sustain the power of the last remnant of their friends in the governmental service, Monarchists hoping to fish once more in troubled waters, anti-Semites and their rowdy city mobs fighting to justify their existence, quiet, patriotic citizens unable to believe that a cause supported by the leaders of the army could be wrong, members of the middle class fearing the growth of the radical and revolutionary forces in the opposite camp. This formidable array of forces, held together by conservatism and patriotism, presented probably the greatest potential danger to the Third Republic since the critical days of the 'seventies.

Nobody could remain neutral in this great struggle, least of all the government. The prime minister Brisson was well aware of this situation and realized its consequences. To reject the request for a revision of the Dreyfus case meant the loss of many Socialist and Radical votes. To accept it meant the hostility of the Nationalists, who were a necessary element of the government's majority. The cabinet was doomed no matter what it did. Confronted with this situation Brisson decided to take his stand with the Dreyfusards, hoping for a union of the republican forces. The Progressists, however, were as hostile as ever. Even the resignation of three ministers of war made them forget their political animosities toward the Radicals only temporarily.[13] Consequently the Brisson cabinet

[13] The minister of war, Cavaignac, had nationalist leanings and refused to be a member of a revisionist cabinet. His successor, General Zurlinden, studied the documents for two weeks and then announced his conviction of the guilt of Dreyfus. The third minister was General Chanoine, who abstained from voting on all questions relating to the revision, but suddenly resigned on October 25, in the midst of the debate on the Dreyfus case. This rather disloyal incident forced the Progressists to vote for Brisson, but at the reopening of the discussion they were free to express their true sentiments.

was defeated on October 25, 1898, by a vote of two hundred and ninety-six to two hundred and forty-three.

With the fall of Brisson the days of the two great coalitions of the right and the left were over. The loss of the Nationalists within the Radical group and the desertion of some Moderates had changed the Union of the Lefts from a majority into a minority party, while the right wing of Méline's former majority was too deeply involved in the recent anti-Semitic and antirepublican agitations to become once more the allies of the conservative, but republican, Progressists. Consequently a government of the center, including both Progressists and Radicals, was the only possible solution. For this task the president of the Republic chose the Progressist Charles Dupuy, a clever but vacillating politician. Though he was hardly the man to cope successfully with the present difficulties [14] and had favored the Progressists in the division of spoils, most republicans decided to give the cabinet a chance to prove its worth. For the first time in five years Radicals and Progressists voted together on a critical occasion.

This sudden coöperation of the two great republican groups failed, however, to develop into a firm alliance. Below the surface the old antagonisms continued. Dupuy was forced to please sometimes the Radicals, sometimes the Progressists, and in the end he pleased neither.[15] But it was the cabinet itself which brought about its own ruin by committing a serious political blunder. Dupuy listened to the criticism of the Nationalists against the criminal chamber of the Cour de Cassation and transferred the request for the revision of the Dreyfus case from this court to one composed of all the divisions of the Cour de Cassation.[16] Though the prime minister was able to have this measure passed by parliament on February 10, 1899,[17] this date marks the beginning of the future *bloc* of the Lefts.

The gravest political consequence of the law was the schism created within the Progressist party. Most of the leaders of the group, except Méline, openly disapproved the government's actions, which interrupted the due process of law and seemed to justify the

[14] Reinach, J., *Histoire de l'Affaire Dreyfus*, IV (Paris, 1906): 351–356.

[15] *Le Temps*, November 11, 12, 23, December 21, 1898.

[16] The Cour de Cassation is divided into three divisions: a criminal chamber, a court of petitions, and a civil court.

[17] The vote was 323 to 208. On this occasion the minister of justice, Lebret, gave his famous advice to the deputies: "Regardez dans vos circonscriptions." — Daniel, *op. cit.*, 1899 (Paris, 1900), p. 63.

attacks of the Nationalists.[18] At the same time the Union of the Lefts was resurrected. Radicals and Socialists, who had voted on opposite sides since the creation of the Dupuy cabinet, discussed the government's bill at a common reunion and decided to vote against it.[19] Moreover, the dissatisfied Progressists joined with the Union of the Lefts to publish a common manifesto against the cabinet's actions.[20] In other words, the apparent influence of the Nationalists on the government had created a republican coalition for the defense of the established institutions.

This new alliance was fostered by the events of the following months. The death of Félix Faure, the president of the Republic, was in itself an incident of only average importance, but it became an event of national significance through the necessity of choosing a successor. Progressists and Radicals, Dreyfusards and anti-Dreyfusards considered the choice of a new president of utmost importance to their cause. Unfortunately for the Progressist group the Nationalists and the Monarchists rallied to the support of its candidate, Méline, thereby making the conservative republicans appear as the friends of the forces of reaction.[21] At the same time the Union of the Lefts obtained a new ally by combining with the majority of the Senate to elect Émile Loubet, the president of the upper chamber. The violent attacks of the Nationalists against the new president of France and the quixotic attempt of Déroulède to overthrow the parliamentary republic [22] increased the strength and the popularity of the new allies, who now could claim to be the true defenders of the Republic.

The final disintegration of the Progressist majority was brought about by the events following the decision of the Cour de Cassation on June 3, 1899, to permit a revision of the Dreyfus case. The undaunted Nationalists refused to consider their cause lost. In fact,

[18] Reinach, *op. cit.*, p. 542; *Le Temps*, February 10, 11, 1899.

[19] Daniel, *op. cit.*, p. 32.

[20] The manifesto may be found in full in Daniel, *op. cit.*, pp. 69–72.

[21] Reinach, *op. cit.*, IV: 557–558.

[22] The mysteries of this attempted *coup d'état* have never been completely cleared up. Its final execution was so childish as to deprive it of all serious consideration. Still, if only a part of the legend which surrounds this incident is true, the existence of the Republic was certainly seriously endangered at the time. — Tharaud, J. and J., *Vie et mort de Déroulède* (Paris, 1925), p. 117; Barrès, M., *Scènes et doctrines du nationalisme* (Paris, 1902), pp. 220–271; *idem*, *Mes Cahiers*, II (Paris, 1930), p. 96.

they redoubled their efforts to "save the army and France from the death grip of the Jewish syndicate." On June 4 they booed and hissed the president of the Republic, and a cane-swinging Monarchist even attempted a bodily attack upon Loubet. Dupuy's failure to provide for the safety of the chief executive did not, however, result in the immediate overthrow of the cabinet. The clever prime minister merely issued a number of decrees against the Nationalists, whose violent attacks against the government forced the groups of the Left to vote for the cabinet.

The opponents of Dupuy, however, were not to be defeated so easily. To organize their attack they formed a Committee of Republican Defense composed of representatives not only from the groups of the Union of the Lefts, but also from the republican groups of the Senate.[23] Moreover, the indefatigable Socialists called out the proletariat of Paris to salute Loubet at the fashionable Longchamps races on June 11, 1899. This republican demonstration created a hopeless dilemma for Dupuy. Special measures of precaution would certainly be considered an insult by the republicans, while the lack of sufficient police protection might lead to serious incidents. Dupuy chose to play safe, but unfortunately for the government no incidents occurred to justify the presence of two regiments of infantry and twenty squadrons of cavalry at Longchamps.

The interpellation of the Socialists on the "insulting measures of precaution against the true defenders of the Republic" gave the disgruntled republicans a chance to show their true opinions. None of the resolutions approved by the government obtained a majority. A motion calling for a cabinet "resolved to defend the republican institution with firmness and energy" was passed by two hundred and ninety-two votes to one hundred and sixty-five. Dupuy's vacillations had led to his downfall and at the same time to the disintegration of the Progressist party. Fifty-nine deputies, more than a quarter of his own party, had voted against Dupuy. In the general political chaos which the Dreyfus Affair had created the Union of the Lefts stood out as the potentially strongest factor.

III

The fall of Dupuy opened the most important ministerial crisis in the twenty odd years of the existence of the Third Republic. The

[23] *Le Temps*, June 9, 1899.

events of the last few months seemed to indicate that the solution of the crisis lay in a government of the left, but the Dreyfus Affair had raised the passions of the opposing factions to such a pitch that a nonpartisan government seemed more likely to survive the crisis. The retrial of Dreyfus was bound to increase the excitement. Not only was a strong leader needed to steer France through this period of storm and stress, but the conditions also demanded an unusual amount of political sagacity among the deputies of the Chamber. Conservatives and radicals would have to forget their differences temporarily. The time for the usual dickering of offices and spoils had passed. The groups which showed the greatest wisdom and unity at this time would inevitably be considered the saviors of France.

As the man best fitted to overcome the present and future troubles, the president of the Republic chose the Progressist senator Waldeck-Rousseau. The latter, however, insisted that the thirty-eight-year-old Raymond Poincaré should make the first attempt at solving the crisis.[24] The young Progressist negotiated for six days, but his desire to keep his own party in power led to his failure. The Radicals were promised only two ministries. Even the present complications could not turn the deputies of the left into political ascetics.[25] Waldeck-Rousseau was the next to try his hand, but this time the senator's own party prevented a solution of the crisis. The Progressists refused to agree with Waldeck-Rousseau in considering the Republic sufficiently endangered to justify the inclusion of the Socialist Millerand in the cabinet.[26] By constantly increasing their demands for guarantees against the Socialists they finally turned a statesmanlike conception into a failure.[27] Two more days were wasted

[24] Illuminating details on the whole period of Waldeck-Rousseau's ministry, not used by J. Reinach in his standard work on the Dreyfus Affair, can be found in the private papers of Waldeck-Rousseau, published by H. Leyret in *Le Matin*, February 4 to March 13, 1911. For the information above see Waldeck-Rousseau, R., "Notes," *Le Matin*, February 6, 1911.

[25] *Le Temps*, June 16, 17, 18, 1899.

[26] Reinach (*op. cit.*, V [1907]: 162) claims the credit for suggesting Millerand as a minister and for convincing Waldeck-Rousseau of the necessity of such a move. However, the more orthodox Poincaré had turned down the help of the Socialists a few days earlier. See speech of R. Poincaré at Nancy, *Le Temps*, May 14, 1901.

[27] Waldeck-Rousseau, "Notes," *Le Matin*, February 6, 7, 8, 1911. The attitude of the Progressists is well represented by the editorials of *Le Temps*, which spoke of the "critical hours of the Republic" and possible revolution only as long as the Socialists were not involved in saving the endangered Republic. Compare *Le Temps* of June 17 with the issues of June 19 and 21, 1899.

in trying to find a Radical to take the leadership, but to no avail. The Radicals, usually only too anxious to replace the Progressists in the government, were loath to assume responsibility at the present critical hour.[28] It was after these none too savory developments that Waldeck-Rousseau performed his "leap in the dark."

On June 22, 1899, he formed a cabinet without consulting his own party, the Progressists. Impressed by the seriousness of the crisis [29] and sick of the system of mutual guarantees and petty bickerings, he gathered his collaborators from the four corners of the political horizon. Not only did the cabinet include the Socialist Millerand to enrage the Progressists, but its minister of war was no other than the Marquis de Galliffet, the butcher of the Commune, hated by the Socialists more than any other general in the French army. Moreover, the Radicals, who were expected to furnish more than half of the majority, had to be satisfied with only two out of eleven ministerial positions. The cabinet seemed to have been formed purposely to test the self-denial of the republicans.

Under these critical circumstances the groups of the left showed the greatest cohesion. The Radicals and Radical-Socialists decided to vote for Waldeck-Rousseau in spite of the unfavorable division of spoils, for the failure of their so-called leaders to attempt a solution of the crisis had left them no other choice.[30] Among the Socialists, however, the new cabinet created the deepest divisions. Jaurès and his twenty-five followers were willing to support Waldeck-Rousseau for the sake of the Republic and in the hope of future social legislation.[31] To Guesde and the remaining Socialists, on the other

[28] Brisson pleaded sickness and Bourgeois claimed that his work at the Hague Peace Conference was of greater benefit to France than any service he might render as prime minister! — Daniel, *op. cit.*, pp. 222–223.

[29] Waldeck-Rousseau, "Notes," *Le Matin*, February 9, 1911; Ribot, M. A., *Discours politiques*, I (Paris, 1905) : ii. The actual danger to the Republican institutions in 1899 is still a matter of controversy. Its existence or nonexistence justifies or condemns the Waldeck-Rousseau combination. The opinion of those who did not believe in the danger of 1899 was more or less vindicated by the subsequent course of events. But what might have happened to France without the firm direction of Waldeck-Rousseau is another one of those great historical "if's."

[30] *Le Temps*, June 25, 27, 1899. In the Radical-Socialist group the decision to support the new cabinet resulted in the resignation of its president, C. Pelletan, and four of his followers. As author of *La Semaine sanglante* Pelletan could hardly be expected to vote for Galliffet, whom he had denounced as the most bloodthirsty general of the Commune.

[31] On Jaurès' actions leading to his final approval of the cabinet see Reinach, *op cit* V : 162–177

hand, Millerand's appointment represented merely another attempt of the capitalists to disarm the proletariat, and therefore the new government did not deserve, even in this crisis, the approval of the true disciples of Marx.[32]

Thus Waldeck-Rousseau could count on nearly two hundred votes from the Union of the Lefts; at least eighty more were needed to assure the defense of the Republic, and these had to come from Waldeck-Rousseau's own group, the Progressists. The united support of this group would have freed the prime minister from a too great dependence on the Radicals, but such a far-sighted policy the Progressists were unable to adopt.[33] Some were Dreyfusards, others anti-Dreyfusards. Some considered the Socialists the greatest danger to France, others the Monarchists and the Nationalists. Consequently when Waldeck-Rousseau asked the Chamber of Deputies for its confidence on June 26, 1899, only eighty-six Progressists voted for him, while one hundred and two opposed him and thirty-one abstained from voting. Still this split among the Progressists was large enough to save the new cabinet from defeat. Its vague program of "Republican Defense," coöperation, and pacification was approved by the narrow majority of twenty-four votes.[34]

With this slight margin of safety Waldeck-Rousseau entered upon his task of reëstablishing order in France. By arresting twenty-three of the most prominent Nationalists he deprived the antirepublican forces of their leaders.[35] The Dreyfus Affair was temporarily liquidated in a manner which satisfied neither the Nationalists nor the Dreyfusards and consequently was probably the best solution for the internal peace of France.[36] Galliffet restored the discipline

[32] The dissenters later published a manifesto denouncing their former comrades. — Weil, *op. cit.*, p. 317.

[33] A meeting of the group, called by Méline, voted against the "Socialist Ministry." — *Le Temps*, June 24, 25, 27, 1899.

[34] Two hundred and sixty-one deputies voted for Waldeck-Rousseau, 237 against him. Some observers claim that the Radical Brisson saved the cabinet by giving the Mason sign of distress to his numerous brethren in the Chamber. — Halévy, D., *Luttes et problèmes* (Paris, 1911), p. 80; Reinach, *op. cit.*, V : 192–193.

[35] Since only three of the accused were convicted of conspiring to overthrow the Republic, Waldeck-Rousseau's actions were severely criticized. — Cochin, D., "Vues politiques," *Nouvelle revue*, October 15, 1899. For a defense of the prime minister see Reinach, *op. cit.*, V : 255–263, 308–313; VI : 206–228.

[36] Dreyfus was again convicted of treason, but the judges, with an illogicality hardly ever equaled, granted the "traitor" extenuating circumstances. Condemned to ten years instead of life imprisonment, Dreyfus was immediately pardoned by the president of the Republic.

in the army.[37] By November, 1899, the crisis had been met successfully. But did the reëstablishment of temporary order end the task of Waldeck-Rousseau? Was not the government of Republican Defense duty-bound to prevent any possible recurrence of the late troubles? Waldeck-Rousseau felt that the answer to the latter question could be only in the affirmative.

The periodic attacks against the Republic in 1877, 1889, and 1899 had involved the same political and social factions: the Church, the army, and the civil service. It seemed obvious that these perennial enemies of the established institutions had to be rendered harmless or trouble was bound to occur again. The republicanization of the army, a change in the procedure of military courts, a new procedure in the recruitment of civil servants, all these measures seemed necessary to assure the safety of the Republic. Above all, however, it was the Church which claimed the government's attention. For the third time it had supported the antirepublican forces almost unanimously. The destruction of the educational and political power of the clergy seemed to be a prerequisite for the internal peace of France. It was a program inspired by these ideas that Waldeck-Rousseau decided to adopt.[38] This decision was to influence the political life of France for the next ten years.

To the political parties in the Chamber the prime minister's new program presented new and serious difficulties. To vote for a government of Republican Defense in a serious crisis was a simple matter compared to the question whether or not to support a government of Republican Attack over a number of years.[39] The Radicals and Radical-Socialists were still chagrined by their underrepresentation in the cabinet, but they realized that they did not possess the necessary majority to form their own government. Moreover, the cabinet's new program was enough like their own platform to deserve their full support, and they could desire no better advertisement than the endorsement of the formerly conservative Waldeck-Rousseau.[40] In the Socialist camp the schism created in June, 1899,

[37] Daniel, *op. cit.*, pp. 294–297, 311, 315.

[38] *Journal officiel, Chambre des Députés, Débats*, 1899, pp. 1816–1819.

[39] Hardly anybody had expected Waldeck-Rousseau to stay in office beyond the duration of the crisis. See *Le Temps*, June 24, 1899; Mirman, L., "Vues politiques," *Nouvelle revue*, October 15, 1899; Ribot, *op. cit.*, p. iii.

[40] Speech of G. Doumergue, November 10, 1899, *Journal officiel, Chambre des Députés, Débats*, 1899, pp. 1857–1858; De Coubertin, P., *Chronique de France*, 1900 (Paris, 1901), p. 62.

continued, but even the "pure" Socialists were willing to support the social reforms of the cabinet, though reserving their freedom of action on any issue conflicting with Socialist principles.[41] Thus the government could count on the support of the entire Union of the Lefts, about two hundred and twenty votes, for the realization of its program.

Among the political groups the Progressists were faced with the greatest dilemma. Though the majority of the ministers were affiliated with this group, the program of the cabinet was contrary to the policy followed by the Progressists for two years under Méline. After having fought and denounced the Socialists, they were now asked to accept them as their allies. They had hoped and worked for the conversion of the Monarchists and the Catholic clergy to republicanism, and now the latter were to be persecuted. Méline and one hundred and twenty of his followers were unable to make this change. To them the Dreyfus Affair had merely proved the weakness of the antirepublicans, who, if only let alone, would die a natural death.[42] More and more Progressists, however, agreed with Waldeck-Rousseau that the recent events necessitated a new policy. Ever since the elections of 1898 deputies had been leaving the Progressist group; some were impressed by their electoral experience, others by the revelations of the Dreyfus case, which had shown the extreme conservatives as inveterate enemies of the Republic.[43] All of them, however, realized that their chances of reëlection would be enhanced by obtaining the support of Radicals.[44] These Progressist dissenters, numbering over eighty in November, 1899, were to be the main support of Waldeck-Rousseau.

Consequently, when the Chamber of Deputies approved Waldeck-

[41] Viviani, R., "Par le socialisme," *Revue politique et parlementaire*, Vol. XXIII, February 10, 1900; Lafargue, P., *Le Socialisme et la conquête des pouvoirs publics* (Lille, 1899).

[42] Méline as cited in note 4; see also the attacks of Méline against Waldeck-Rousseau, *Le Temps*, September 15, 23, December 24, 1899, and the speech of Krantz, president of the Progressist group, *Le Temps*, March 8, 1900.

[43] Cf. Letter of Ch. Jonnart to Méline, *Le Figaro*, September 24, 1899; Étienne, É., *Son œuvre coloniale, 1881–1906, Discours et écrits divers* (Paris, 1906), pp. 336–346; Wallier, R., *Le Vingtième Siècle politique*, 1901 (Paris, 1902), pp. 344–346.

[44] Most of these supporters of Waldeck-Rousseau came from the north and the west of France, where the strength of the conservative forces had made the deputies the leaders, not of a republican faction, but of the whole republican party.

Rousseau's program on November 14, 1899,[45] the political consequences of the Dreyfus Affair became clear. The stage was set for a "New Deal" in French politics through the emergence of the Union of the Lefts as the controlling factor within the French parliament. In existence ever since the first years of the decade, this alliance of Radicals, Radical-Socialists, and Socialists had grown from a minority into a majority party through the adhesion of the left-wing Progressists. This new combination was to be called the *bloc* of the Lefts, and its leaders were to be in power for the next ten years.

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[45] The vote was 319 to 211.

SOPHOCLES AND THE PATHETIC FALLACY

FRANK OLIN COPLEY

BRIEFLY defined, the pathetic fallacy is the expression of the illusion, produced by mood or emotion, that the inanimate world is a sentient thing, that it feels emotions as human beings do, and even on occasion shows sympathy with the sorrows and the joys of mankind.[1] The figure lends itself readily to the mental habits of the romantic and sentimental poet, yet it is as old as Homer, and is to be found in one or another form in nearly every one of the Greek poets of the classical age. Of the tragedians, Aeschylus has left in some of his finest passages examples of the pathetic fallacy that quite equal those of the modern poets in brilliance and depth of passion.[2] And in Sophocles' plays its use reaches a height of artistry and beauty to which the later poets seldom attained. For with Euripides it tends to become artificial, and the Hellenistic poets have made it a pretty conceit.[3]

Of the seven extant tragedies of Sophocles, the two which are richest in examples of the pathetic fallacy are the *Ajax* and the *Philoctetes*, respectively the first and the next to last in order of composition. The *Oedipus at Colonus*, the last play, reveals no examples whatever, while the remaining plays afford one or two each. There is, then, no correlation between date of composition and frequency of the pathetic fallacy, nor would such a correlation be of any real value by itself. Rather, since the pathetic fallacy if used to excess or inappropriately may degenerate into bombast or sentimentality,[4] we must examine Sophocles' use of it to determine how

[1] The doctrine and the name of this phenomenon were first propounded by John Ruskin in his essays "Of the Pathetic Fallacy" (*Modern Painters*, Part IV, Chap. XII) and "Of the Imagination Contemplative" (*ibid.*, Part III, Sec. II, Chap. IV).

[2] E.g. *Prom.* 1044-1053, with which compare Shakespeare, *King Lear*, Act III, Sc. 2.

[3] Some reservations to this statement must be made, notably in the case of Theocritus.

[4] Cf. Ruskin, "Of the Pathetic Fallacy," paragraph 7.

far he avoids these faults. Again, the pathetic fallacy comes most easily to the poet who feels the existence of a sympathy and companionship between himself and inanimate things, and it will be of interest to see how deeply Sophocles experienced this feeling, normally considered the all but exclusive property of the romantic poet. It will, of course, be impossible in a study of this scope to discuss all the examples.[5] I shall confine myself to those which are most interesting and significant.

The lonely and morbid Antigone, whose only crime was that she loved her brother more than she respected the cruel laws of Creon, was condemned by him to be buried alive in a cave. Possessed by the thought that the consolations of the chorus are intended to mock her, she calls the springs of Dirce and the glade of Thebes to witness her shameful treatment:

> οἴμοι γελῶμαι. τί με, πρὸς θεῶν πατρῴων,
> οὐκ οἰχομέναν ὑβρίζεις, ἀλλ' ἐπίφαντον;
> ὦ πόλις, ὦ πόλεως πολυκτήμονες ἄνδρες·
> ὦ Διρκαῖαι κρῆναι
> Θήβας τ' εὐαρμάτου ἄλσος. ἔμπας ξυμμάρτυρας ὕμμ' ἐπικτῶμαι,
> οἷα φίλων ἄκλαυτος, οἵοις νόμοις
> πρὸς ἔργμα τυμβόχωστον ἔρχομαι τάφου ποταινίου·
> ἰὼ δύστανος, βρότοις οὔτε νέκροις κυροῦσα
> μέτοικος, οὐ ζῶσιν, οὐ θανατοῦσιν.[6]

Alas, I am mocked! Why, by our fathers' gods, do you not await my death, but heap outrage on the living? O my city, O my city's wealthy sons!

O you springs of Dirce, and you sacred glade of Thebes, rich in chariots, you at least have I for witnesses how unwept of friends and by what laws condemned I go to a chamber sealed like a tomb, an outlandish sepulcher! Ah, for my ill fortune! Neither among men nor among shades have I my dwelling, neither with the living nor with the dead!

Antigone, as Butcher has said,[7] calls out as one "deserted and alone" to a nature which is no more to her than a last resort now

[5] I have collected them all in my dissertation (unpublished), *The Pathetic Fallacy in Greek Poetry from Homer to the Close of the Fifth Century* (Stanford University, 1935).

[6] *Ant.* 839 851.

[7] Butcher, S. H., *Some Aspects of the Greek Genius* (London, 1929), p. 282.

that she can no longer expect sympathy of mankind, and we are to see in this fact, he continues, an essential difference between Sophocles' viewpoint and that of the romanticist. But back of all the modern poet's fleeing to nature is that same feeling of an unsympathetic mankind, or at least of a more sympathetic nature. It is only the modern man's tendency to flee there on less provocation that sets him apart from the Greek. And the true sentimentalist is continually longing for the companionship of his egoistic self which he finds reflected in tree, cloud, and river, his refuges from men who do not understand him. The saner Sophocles reserves such outcries for the moment when humanity has been truly deserted by its own kind, when great emotion floods an unhappy soul. At such times it is only right and appropriate that man should succumb to subjective emotion rather than cling doggedly to objective reason.[8]

It is in a similar moment that Oedipus cries out to Mount Cithaeron, the house "that was in name my father's," and the "three roads" that beheld the awful killing of a father by his son.[9] Why, why could they not have saved him from all this sorrow? For they must have felt, as he feels now, the revolting lie that he was living. Again, it is the utterly abandoned soul that speaks, and turns as it should to seek sympathies that are only subjectively and not objectively real.[10]

But the pathetic fallacy need not always be the expression of overwhelming passion. It may result from that contemplative mood with which the sensitive poet views nature, a mood that is no sign of morbidness or disarranged thought, but of imagination and a real affection for the beauty of the inanimate world.[11] In the *Trachiniae*, Deianeira, reminding the chorus that they are too young to under-

[8] Cf. Ruskin, "Of the Pathetic Fallacy," paragraph 14: "A poet is great, first in proportion to the strength of his passion, and then, that strength being granted, in proportion to his government of it; there being, however, always a point beyond which it would be inhuman and monstrous if he pushed this government, and, therefore, a point at which all feverish and wild fancy becomes just and true."

[9] *Oed. Tyr.* 1391–1403.

[10] Creon also calls on Oedipus' attendants to feel shame at showing his stain before the face of nature, as if nature herself would be horror-struck (*Oed. Tyr.* 1422–1431). But the thought here is profoundly influenced by religious concepts, and is less a spontaneous outburst of passion: compare Jebb on vs. 1427.

[11] This doctrine is the particular subject of Ruskin's essay "Of the Imagination Contemplative"; the two phenomena of thought are, however, essentially identical.

stand her sufferings, compares the young girl to a young plant in terms that clearly show the extension of human experiences to the inanimate:

> τὸ γὰρ νεάζον ἐν τοιοῖσδε βόσκεται
> χώροισιν αὐτοῦ, καί νιν οὐ θάλπος θεοῦ
> οὐδ' ὄμβρος, οὐδὲ πνευμάτων οὐδὲν κλονεῖ,
> ἀλλ' ἡδοναῖς ἄμοχθον ἐξαίρει βίον
> ἐς τοῦθ' ἕως τις ἀντὶ παρθένου γυνὴ
> κληθῇ, λάβῃ τ' ἐν νυκτὶ φροντίδων μέρος,
> ἤτοι πρὸς ἀνδρὸς ἢ τέκνων φοβουμένη.[12]

For young life is nourished in spots of its own, and is not troubled by the god's heat, nor by the rain, nor by any manner of wind. Nay, midst joys it exults in a life that knows no toil — up to that time when one is called woman instead of girl, and takes one's share of the night's anxious thoughts, beset with care for husband, mayhap, or children.

In the tender plant — for this must be the meaning at least in the first four lines of the passage of the ambiguous term τὸ νεάζον ("young life") — Sophocles saw reflected the qualities of childhood, peace, innocence, and joy. And how poignant this thought, since become so commonplace,[13] seems in the mouth of Deianeira! It pictures a mind not full of sentimental world weariness but pervaded, wistfully rather than bitterly, with a sense of a unity in the world, a unity of sadness. To Deianeira, deprived of the thing which was her life, the love of Heracles, animate and inanimate alike seem to know a joyful beauty that turns to care through sheer force of the order of things. Motivated by introspective egoism, the thought would have been sentimental; here it is full of true pathos.

Very skillfully used is the pathetic fallacy in Electra's first speech:

> ὦ φάος ἀγνὸν
> καὶ γῆς ἰσόμοιρ' ἀήρ, ὥς μοι
> πολλὰς μὲν θρήνων ὠδάς,
> πολλὰς δ' ἀντήρεις ἤσθου
> στέρνων πληγὰς αἱμασσομένων,
> ὁπόταν δνοφερὰ νὺξ ὑπολειφθῇ·
> τὰ δὲ παννυχίδων ἤδη στυγεραὶ

[12] 144–150.

[13] E.g. in Wordsworth's *Daffodils*.

ξυνίσασ' εὐναὶ μογερῶν οἴκων,
ὅσα τὸν δύστηνον ἐμὸν θρηνῶ
πατέρ' . . . .[14]

O pure light, and air that spreads o'er all the earth, how many lamentations have you heard me utter, how many blows heard shed upon my bleeding breast, when shadowy night fails! Yea, and my hated couch within the halls I loathe knows well ere now of the watches that I keep, how many a groan I utter for my hapless father.

In thus telling her tale to these inanimate things Electra shows how far she is gone in loneliness and grief. She has no more faith in the consolations of men, for they cannot know the true depth of her sufferings.[15] By a sort of desperation she is driven to seek a sympathy, vaguely realized and expressed, in the light and air of heaven, and even in the bed she detests. These are rather comfortless witnesses, but they are all she has.

But there are passages in Sophocles' plays in which the inanimate is appealed to for sympathy not merely because there is no other course left but because in some way a companionship has sprung up between the character and his surroundings. Ajax has been long at Troy, and it is with a feeling of horror and shame before these places that he turns to die:

ἰὼ
πόροι ἁλίρροθοι
πάραλά τ' ἄντρα καὶ νέμος ἐπάκτιον,
πολὺν πολύν με δαρόν τε δὴ
κατείχετ' ἀμφὶ Τροίαν χρόνον· ἀλλ' οὐκέτι μ', οὐκ
ἔτ' ἀμπνοὰς ἔχοντα· τοῦτό τις φρονῶν ἴστω.
ὦ Σκαμάνδριοι
γείτονες ῥοαί,
εὔφρονες Ἀργείοις,
οὐκέτ' ἄνδρα μὴ
τόνδ' ἴδητ', ἔπος
ἐξερῶ μέγ', οἷον οὔτινα
Τροία στρατοῦ δέρχθη χθονὸς μολόντ' ἀπὸ

[14] *Elec.* 86–95.
[15] Compare her words to the chorus, vss. 145–309.

Ἑλλανίδος· ταυῦν δ' ἄτιμος
ὧδε πρόκειμαι.[16]

Alas, you paths of the sea, and you sea caves and meadows by the shore, far, far too long have you held me now about Troy — but 'tis no longer one who lives and breathes: this let every man of understanding know. O near-by streams of Scamander, you who were kindly to the Argives, no more will you behold Ajax — a mighty word I speak — a man like none other whom Troy beheld coming in the host from Hellas. But now so low I lie in shame!

And again:

ἐχθαίρομαι, μισεῖ δέ μ' Ἑλλάνων στρατός,
ἔχθει δὲ Τροία πᾶσα καὶ πεδία τάδε.[17]

Loathed am I; the host of Hellenes hates me; all Troy and these plains abhor me!

It is a man consumed by horror and shame who speaks, and his words are the truest expression of the feelings of such a man. These inanimate things seem to be old friends who had shared his glory and now must look upon his shame. Similarly, and with an admixture of almost sentimental nostalgia, Ajax addresses Athens, Salamis, and these same plains of Troy:

ὦ φέγγος, ὦ γῆς ἱερὸν οἰκείας πέδον
Σαλαμῖνος, ὦ πατρῷον ἑστίας βάθρον,
κλειναί τ' Ἀθῆναι, καὶ τὸ σύντροφον γένος,
κρῆναί τε ποταμοί θ' οἵδε, καὶ τὰ Τρωικὰ
πεδία προσαυδῶ, χαίρετ', ὦ τροφῆς ἐμοί·
τοῦθ' ὑμῖν Αἴας τοὔπος ὕστατον θροεῖ·
τὰ δ' ἄλλ' ἐν Ἅιδου τοῖς κάτω μυθήσομαι.[18]

O light of day, O holy soil of my homeland, Salamis, O threshold of my fathers' hearth! O far-famed Athens, and you people that are kin to mine, and you, too, you springs and rivers here, and Trojan plains: I call to you, 'Farewell, you who nourished my life!' This is the last cry that Ajax makes to you. The rest I'll tell to those below in Hades.

[16] *Ajax* 411–427. Alfred Biese says of this passage that it exhibits "die zarteste Sympathie zwischen Natur und Menschen." — "Die poetische Naturbeseelung bei den Griechen," *Zeitschrift für Völkerpsychologie und Sprachwissenschaft*, 20 (1890): 252.

[17] *Ajax* 458–459.

[18] *Ibid.*, 859–865.

In all these passages nature has clearly become something more than the mere last resort of an abandoned soul. Before Tecmessa and the chorus Ajax has been filled only with sorrow and regret.[19] They were his friends and comrades, but they do not understand how deeply he feels.[20] In the end he puts them roughly aside.[21] The scenes amid which he has lived a glorious life — these have been his most sympathetic companions; these alone can know the tragedy that has overwhelmed him. His last word is for them. What consolation he finds in them he does not say, yet it is with a species of calm that he speaks his last line:

> τὰ δ' ἄλλ' ἐν Ἄιδου τοῖς κάτω μυθήσομαι.
>
> The rest I'll tell to those below in Hades.

It is in the *Philoctetes* that Sophocles expresses most clearly the thought that man can achieve companionship with the inanimate, and that nature can in some measure offer relief and consolation for human troubles, can in a word take the place of a sympathetic human heart.[22] Even the bow of Heracles, which has served Philoctetes in his long stay on Lemnos, has acquired in his eyes the qualities of a faithful servant, who must resent the trickery of Odysseus and Neoptolemus.[23] Pathetically he cries out to beach, headland, and cave, "his wonted comrades," to take pity on him for the treatment he has received from Neoptolemus,[24] and when, cheated of his bow, he finally gives up all hope of leaving the island, and foresees his death there, it is to his cave that he addresses his lament:

> ὦ κοίλας πέτρας γύαλον
> θερμὸν καὶ παγετῶδες, ὥς σ' οὐκ ἔμελλον ἄρ', ὦ τάλας,
> λείψειν οὐδέποτ', ἀλλά μοι καὶ θνήσκοντι συνείσει.
> ὤμοι μοί μοι.
> ὦ πληρέστατον αὔλιον
> λύπας τᾶς ἀπ' ἐμοῦ τάλαν,
> τίπτ' αὖ μοι τὸ κατ' ἆμαρ
> ἔσται; τοῦ ποτε τεύξομαι
> σιτονόμου μέλεος πόθεν ἐλπίδος;[25]

[19] Cf. *ibid.*, 349–370. [20] Cf. *ibid.*, 349, 360. [21] *Ibid.*, 589–593.
[22] Cf. Biese, Alfred, *Die Entwicklung des Naturgefühls bei den Griechen* (Kiel, 1882), pp. 45–46.
[23] *Philoct.* 1128–1136. [24] *Ibid.*, 936–940. [25] *Ibid.*, 1081–1091.

O hollow of the cavernous rock, now hot, now frosty-cold, so it was to be, that I should never leave you, hapless as I was! Nay, you will be witness even to my death. Ah, for my woe! O house of mine, filled to the full with the sad tale of my misery, what now shall be daily sustenance for me, unhappy man? Where, whence in my wretchedness shall I take hope of food?

Yet it might be said of these passages that Philoctetes has found companionship with nature solely because it was forced upon him. "This personal converse with the world outside," says Butcher,[26] "is for Philoctetes an enforced intercourse. A kindly sentiment has indeed sprung up in his mind towards the unhuman companions of his solitude; but the long years he has spent alone with nature have wrought no healing, they have not caused forgetfulness of the sweet society of man." This is true. In all the plays of Sophocles, with the possible exception of the *Ajax*, man has not been pictured as preferring nature to his own kind, as finding a solace there that makes him forget other men. Such consolation can be found only by the truly romantic poet. But there is a point between this extreme romanticism and the attitude which sees in nature only an appeal of last resort. If Philoctetes would not have sought the loneliness of Lemnos by preference, he might yet have gained an affection for the island which would cause him some pangs, however faint, at leaving it. To this feeling he does attain, and he expresses it in his last speech, in which he turns to offer his farewell to the scene of his banishment:

φέρε νυν στείχων χώραν καλέσω.
χαῖρ', ὦ μέλαθρον ξύμφρουραν ἐμοί,
Νύμφαί τ' ἔνυδροι λειμωνιάδες,
καὶ κτύπος ἄρσην πόντου προβολῆς,
οὗ πολλάκι δὴ τοὐμὸν ἐτέγχθη
κρᾶτ' ἐνδόμυχον πληγαῖσι νότου
πολλὰ δὲ φώνης τῆς ἠμετέρας
Ἑρμαῖον ὄρος παρέπεμψεν ἐμοὶ
στόνον ἀντίτυπον χειμαζομένῳ.
νῦν δ', ὦ κρῆναι Λύκιόν τε ποτόν,
λείπομεν ὑμᾶς, λείπομεν ἤδη,
δόξης οὔ ποτε τῆσδ' ἐπιβάντες.
χαῖρ', ὦ Λήμνου πέδον ἀμφίαλον.

[26] *Op. cit.*, p. 283.

καί μ' εὐπλοίᾳ πέμψον ἀμέμπτως,
ἔνθ' ἡ μεγάλη Μοῖρα κομίζει
γνώμη τε φίλων χὠ πανδαμάτωρ
δαίμων, ὃς ταῦτ' ἐπέκρανεν.[27]

Come now, as I depart I'll invoke this spot. Farewell, O house that kept the watches with me; farewell, Nymphs of stream and meadow, and farewell, hoarse roar of the sea's promontory, where many a time my head as it rested within that cavern has been wet by the blasts of the south wind, and where many a time the mount of Hermes has sent back a groan in answer to me as I lay storm-tossed! But now, O fountains and Lycian waters, I leave you, leave you even now, I who never entered upon this thought. Farewell, O sea-girt isle of Lemnos, and send me forth with godspeed and without reproach. Send me where mighty Fate takes me, Fate and the counsel of friends, and that all-subduing Spirit who has fulfilled these things!

It would be too much to say that Philoctetes regrets that he has been given back to the society of men. But it is not too much to say that in spite of the trouble, pain, and loneliness of that long sojourn, he realizes that he is leaving behind him a very real sympathy, something which he will miss even among his human friends. Here is a cave that "kept the watches" with him. Will men do the same? Here is a mountain that shared his groans of anguish. Will human friends be as sympathetic? "Send me forth," he says, "without reproach that I have preferred men to you."[28] That Sophocles should have closed the play on this subjective note, this elaborate pathetic fallacy, is emphasis of his realization that man and nature were sometimes, at least, akin. For the lonely, grief-stricken, defeated and thwarted man there is in the inanimate world some answering voice which will be found when the need arises. Man does not

[27] *Philoct.* 1452–1468.

[28] This is Seyffert's interpretation of πέμψον ἀμέμπτως. Jebb and others have preferred to interpret "Send me forth in such way that *I* shall have no cause for reproach," and Campbell has rejected Seyffert's interpretation as being "too finely drawn." I prefer it, and for the following reasons: (1) the idea of a safe voyage has already been expressed by εὐπλοίᾳ; ἀμέμπτως, if Jebb's view be accepted, is no more than a tautology; (2) Philoctetes has just addressed the island in terms of the deepest affection, yet he shows that he is glad to leave it: what is more natural than that he should as it were ask pardon for that gladness? The thought seems to be "You and I have lived in deepest sympathy. You have solaced my sorrow and shared my pain. Do not reproach me now if in spite of that I am glad to leave you, but remember that I am a man, and send me forth with your blessing."

depend entirely on other men or even on the kindness of the gods; beyond these things which we can know and of which we can speak objectively there is something else. Sophocles' pathetic fallacies are the expression of this conviction. If he does not lose himself in nature as the sentimental poet does, it is not because he is less able to see the things that the sentimental poet sees. Rather, it is because he is more capable of facing objective reality and less prone to hide his sorrows in the consolations of an imaginary, subjective world.

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SOME RECENT INTERPRETATIONS OF THE ARISTOTELIAN ENTHYMEME

JAMES H. McBURNEY

LANE COOPER, the only man in America who has translated the *Rhetoric* of Aristotle into English, recently said:

> . . . while Aristotle probably did not give the final utterance on poetic art and spoken prose, and no one ever will succeed in giving it, nevertheless the individual student is not likely to come nearer to that final utterance than Aristotle did unless he patiently goes with Aristotle as far as Aristotle will guide him. . . . One fine quality in Aristotle is his excellent perspective, so that those who go to school to him become less likely to mistake the trivial for the important. Another is his wonderful fertility in germinal thoughts.[1]

For the last several years I have been making a study of the enthymeme, a concept which originates with Aristotle and to which he refers as "the very body and substance of persuasion." [2] J. Barthelemy Saint-Hilaire says of the Aristotelian enthymeme in an appendix to his French translation of the *Rhetoric:*

> It occupies in the art of oratory essentially the place that the syllogism occupies in logic. If one does not know how to make enthymemes, he can hardly flatter himself as being an orator.[3]

In this paper I am proposing some interpretations of the Aristotelian enthymeme which I think have important implications for contemporary speaking and writing. Despite the essentially Aristotelian character of contemporary rhetorical theory and the central place which the enthymeme occupies in Aristotle's rhetorical system, there has persisted for many centuries a strange misunderstanding of this important concept. The enthymeme is today almost universally defined by logicians and rhetoricians alike as an elided syllo-

[1] Cooper, Lane, "The Rhetoric of Aristotle," *The Quarterly Journal of Speech*, 21 (1933) : 12.

[2] *The Rhetoric of Aristotle*, translated into English by Lane Cooper (D. Appleton & Co., New York, London, 1932), I.1.1354[a].

[3] Saint-Hilaire, J. Barthelemy, *Rhetorique d'Aristote* (Paris, 1870), II : 348.

gism. It is commonly differentiated from the logical syllogism only in the omission of one of the propositions of a complete syllogism, with the result that most rhetorical treatises attempt to make the logic of the *Organon* the logic of rhetorical invention. This confusion between logic and rhetoric in respect to the syllogism and the enthymeme has its beginning in a very early misunderstanding of Aristotle's meaning to which I shall refer later.

Aristotle, in his *Organon* and *Rhetoric*, is attempting to set forth a system by which truth and certainty in respect to human knowledge, may be ascertained and demonstrated verbally; by which truth may be sought through discourse; and by which people may be convinced and persuaded. In the *Prior* and the *Posterior Analytics* he develops the apodeictic or scientific syllogism as the method of ascertaining truth and demonstrating it verbally; in the *Topics* he develops the dialectical syllogism as a method by which truth may be sought through discourse; and in the *Rhetoric* he sets forth the enthymeme or the rhetorical syllogism as the basis of convincing and persuading people through speaking and writing. In the last few centuries especially there has developed a large body of literature which is critical of the Aristotelian tradition. Much of this has been directed at the syllogism and some of it at the rhetorical applications of the syllogism. Both Bacon and Locke questioned the usefulness of the syllogism in rhetoric. Campbell, in his *Philosophy of Rhetoric*, after distinguishing between demonstrative or scientific reasoning and moral or probable reasoning, declares rather flatly that the syllogism "has not the least affinity to moral reasoning" and refers to it as a "very incommodious form" attendant with "many disadvantages" in scientific reasoning.[4] Many contemporary treatises on rhetoric argue the impotency of the syllogism in speaking and writing. The really astonishing thing about this whole matter, however, is the oblivion into which the enthymeme seems to have passed. I think there can be no question but that the enthymeme is the concept which we must understand if we are fairly and competently to evaluate the rhetorical applications of the syllogism. My purpose here is not to attack or to defend the usefulness of the enthymeme in contemporary rhetoric or to question the rightness or the wrongness of Aristotle's position. Neither is

[4] Campbell, George, *Philosophy of Rhetoric* (Harper and Brothers, New York, 1859), pp. 63–72.

it my purpose to consider the enthymeme in terms of recent logical and rhetorical developments. My purpose, rather, is to contribute to an understanding of the Aristotelian enthymeme, to interpret Aristotle's position in his own terms, to place the enthymeme properly in his own logical and rhetorical system. I emphatically contend that critical observations on the rhetorical applications of the syllogism are not significant without a proper understanding of the enthymeme, and I contend further that such an understanding should constitute the point of departure for contemporary studies in rhetorical invention.

I. The Enthymeme as a Syllogism from Probable Causes and Signs

First of all, Aristotle very clearly identifies the enthymeme with probable matter as distinguished from that of the syllogism proper, which he considers to be certain and apodeictic. In the *Prior Analytics*, II.27, and in the *Rhetoric*, I.2, and II.25, he defines the enthymeme as a syllogism drawn from *probabilities* and *signs* and thereby expressly distinguishes it on a material basis from the logical syllogism. Some explanation of *probabilities* and *signs* will be helpful here. The distinction that is meant appears to be one which Aristotle frequently uses in the *Organon* — a distinction between *a reason for the being of a fact* and *a reason for acknowledging its being*. These conceptions are often designated *ratio essendi* and *ratio cognoscendi*, respectively. H. W. B. Joseph illustrates this distinction very simply as follows:

> When I say that wheat is nourishing because it contains nitrogen and carbon in certain proportions, I give the reason for its being nourishing. When I say that Mellin's Food is nourishing because Baby grows fat on it, I do not give the reason for its being nourishing, but only the reason for my thinking it to be so: it is not Baby's condition which makes it nourishing, but its nourishing properties which produce Baby's condition.[5]

The point I am making is that Aristotle is designating the materials of the enthymeme as *probabilities* understood as *rationes essendi* and *signs* or *rationes cognoscendi*. In other words, he recognizes two sorts of argument, reasoning from probable causes and reasoning from signs. He is saying that the speaker or the writer may

[5] Joseph, H. W. B., *An Introduction to Logic* (Second edition revised, Oxford, 1916), p. 305.

support a proposition in argument, or elicit belief in a proposition, by setting forth probable causes of the phenomenon which the proposition expresses or by signs that the phenomenon actually does exist.

Whately recognized this great division of argument in his *Elements of Rhetoric* and credited Aristotle with it. The trilogy which he set up, antecedent probability, sign, and example (with example understood as a species of sign), has been followed by most contemporary rhetoricians. Curiously enough, however, the Aristotelian distinction between antecedent probability and sign, while accurately set forth by Whately, has not been consistently applied to the same terms by subsequent writers. Furthermore, the relations of these argumentative types to the enthymeme, and hence to the syllogism, have been both neglected and misunderstood.

It is of first importance to notice in this connection that Aristotle explicitly points out that many enthymematic arguments which are perfectly acceptable from a rhetorical standpoint are lacking in the formal validity which we expect of the logical syllogism. For instance, he mentions three sorts of argument from sign, the infallible sign, the fallible sign, and argument by example or rhetorical induction. Of these, the fallible sign appears typically in the second figure of the categorical syllogism and can never achieve formal validity. Argument by example appears in the third figure and is likewise unable to attain to formal validity. While high degrees of probability may be obtained by these arguments, they cannot be thrown into formally valid syllogisms.

We may say, then, that the enthymeme on the material side is drawn from probabilities, premises representing common beliefs, widely accepted doctrines, maxims, and the like; and on the formal side, is unable to achieve validity in several of its important types. Aristotle emphasizes this point in discussing the refutation of enthymematic argument. He says in part:

> Now since the Probable is that which happens as a rule but not always, it is clear that enthymemes setting forth Probabilities are always open to refutation: that is, you may raise an objection to them, though the objection is not always valid, but may be spurious; for the objector can refute a conclusion by showing, not that it is not probable, but that it is not inevitable. Thus it is always possible to gain an unfair advantage by the use of this fallacy. . . . Therefore it is not enough if the defendant shows that the charge is not necessarily true; he must refute it by showing that it is not likely to be true.[6]

[6] *Rhetoric*, II.25.1402^{b}–1403^{a}.

Aristotle continues concerning the refutation of arguments based on signs:

> Fallible Signs, and the enthymemes which employ them, can be refuted, even if the facts are correct . . . ; for we have shown in the *Prior Analytics* II.27 that no Fallible Sign can enter into a strictly logical proof.
>
> Enthymemes depending upon Examples may be refuted in the same way as those depending upon Probable Causes. A single negative instance on our side will disprove the conclusion of our opponent, so far as concerns its necessity, even though a majority of instances of the usual course of things is against us.
>
> Infallible Signs, and enthymemes taken from them, cannot be refuted on the ground that they are logically inconclusive. . . . Our only resource is to prove that the fact alleged does not exist.

Aristotle's discussion of *topoi* or topics is also important in understanding his conception of the enthymeme as a "syllogism drawn from probable causes and signs." The *topoi*, according to Aristotle, were the places, or heads, or categories to which the speaker and the writer might turn for their arguments. These *topoi* constitute for the speaker a repertory of relatively specific facts, general principles of probability, and various lines of arguments which he may draw upon in formulating his enthymemes. Of importance here is Aristotle's distinction between *general* and *special* topics. He points out that rhetoric and dialectic are peculiarly concerned with general rules of probability which are applicable to all fields of thought indifferently. It is his position that to the degree the rhetorician draws on the special topics or the more his premises represent specific facts and the better he chooses his premises, "the more he imperceptibly glides into some discipline other than dialectic and rhetoric; for if he lights upon true scientific principles, the art is no longer dialectic or rhetoric, but is the discipline based upon these principles." [7] This position is, of course, wholly consistent with what Aristotle has said in many other places, that dialectic and rhetoric deal with general principles of probability applicable indifferently to all fields of thought and capable of being adduced to establish theses in widely different fields. What he refers to as "special topics," because of their specific or sectional character, are not, properly speaking, within the province of rhetoric. Rhetoric cannot be expected to be conversant with the special facts and data of all fields of thought.

[7] *Ibid.*, I.2.1358ª.

Despite this rather clear declaration of the general *topoi* as the special province of rhetoric, Aristotle makes what appears to be a rather startling statement to the effect that "enthymemes are mostly formed from these particular and special topics." [8] This statement can be explained in two ways. Aristotle recognizes the importance of having specific, factual premises in speaking and writing wherever possible and the value of avoiding what he calls the "sheer commonplace." [9] Furthermore, he explicitly recognizes the close relationship between rhetoric and ethics and politics, and the importance of the subject matter of these fields as sources for the speaker's enthymemes. Aristotle states:

> . . . a skilled speaker must have a thorough and detailed knowledge of the special sciences which mainly concern the art of rhetoric — that is, Ethics and Politics, above all, since they have to do with the conduct of men as individuals, and with men in groups. Of course he must have an adequate knowledge of other special sciences, too; no knowledge comes amiss to the speaker.[10]

Students of the *Rhetoric* know that Aristotle takes pains to familiarize his readers with what he considers to be useful information on ethics, and politics, constituting in reality a practical psychology for the speaker and the writer to guide them in adjusting their enthymemes to those individuals whose thinking they hope to influence. This treatment leads me to the second major interpretation of the enthymeme I wish to make, viz. its relationship to what he designates the three great modes of persuasion, *Ethos*, *Pathos*, and logical argument.

II. The Enthymeme in Relation to *Ethos* and *Pathos*

We have seen the enthymeme as a rhetorical syllogism drawn from probable causes and signs. The question I wish now to consider is, Just what are the relationships of the enthymeme to the three great modes of persuasion designated in the *Rhetoric?* Aristotle's description of these is in part as follows:

> Of the modes of persuasion furnished by the spoken word there are three kinds. The first kind depends on the personal character of the speaker; the second on putting the audience into a certain frame of mind; the third on the

[8] *Rhetoric*, 1.2.1358[a].

[9] *Ibid.*, II.22.1396[a] and 1396[b].

[10] *Ibid.*, II.22.1395[b]. See Cope, E. M., *An Introduction to Aristotle's Rhetoric* (Macmillan and Co., London and Cambridge, 1867), p. 9.

proof, or apparent proof, provided by the words of the speech itself. Persuasion is achieved by the speaker's personal character when the speech is so spoken as to make us think him credible. We believe good men more fully and more readily than others; this is true generally whatever the question is, and absolutely true where exact certainty is impossible and opinions are divided. . . . Secondly, persuasion may come through the hearers, when the speech stirs their emotions. Our judgements when we are pleased and friendly are not the same as when we are pained and hostile. . . . Thirdly, persuasion is effected through the speech itself when we have proved a truth or an apparent truth by means of the persuasive arguments suitable to the case in question.[11]

The usual interpretation of Aristotle here is that the enthymeme is the instrument of rhetorical demonstration or proof, and as such does not enter into ethical and pathetical persuasion. I raise the question, Does Aristotle in fact mean to exclude the enthymeme from the realm of *ethos* and *pathos?* The answer to this question is of considerable importance because upon it hinges the relationship of the logical and the nonlogical or emotional factors in argumentative discourse. Are we to consider the logical structure of an argument (which for Aristotle is an enthymematic structure) something that is separate and distinct from the so-called emotional appeals? The question before us, in other words, is, What part if any does the enthymeme play in that mode of persuasion which depends upon the personal character of the speaker (*ethos*) and that which attempts to affect the emotional state of the listener (*pathos*)?

To begin with, we must recognize that the enthymeme is a rhetorical device and as such is dependent, so to speak, upon language symbols, i.e. terms and propositions in significant combinations. Persuasion arising from the personality of the speaker and other kindred factors (except as it finds its expression in terms and propositions) is therefore outside the realm of the enthymeme. But what about the personality appeal and attempts to influence the emotional state of the auditor which are expressed in words and sentences? Here we have the real question, Is the enthymeme the controlling unit of expression in such persuasion, or is it a purely logical instrument of proof?

A careful analysis of Aristotle will reveal the superficiality of attempting to separate the enthymeme from these "nonlogical" methods of persuasion. I submit that in Aristotle's system the enthymeme is the element or unit of *all* persuasive discourse. The

[11] *Rhetoric*, I.2.1356[a].

admission of "emotionally loaded" terms and propositions is in fact one of the important characteristics of the enthymeme; the premises which compose an enthymeme are usually nothing more than the beliefs of the audience which are used as signs and causes to secure the acceptance of other propositions. These premises, as we have seen, are drawn from the general and special topics or *topoi*. Here Aristotle gives us his semipopular discussion of ethics and politics, virtues, vices, and emotions organized around lists of these topics. My point is that Aristotle presents what he has to say about both ethical and pathetical persuasion in the form of topics, and we are explicitly told that these topics are the sources to which we may turn for the propositions to compose enthymemes.

One of the strongest arguments to justify the position I am taking on the enthymeme in relation to *ethos* and *pathos* is to be found in the order of treatment or sequence of the *Rhetoric*. Aristotle begins this *work* by proclaiming the enthymeme to be the body and substance of all persuasion. In Book I, Chapter 2, he distinguishes among the three forms of artistic persuasion and explains the enthymeme in terms of causes and signs. He concludes the same chapter by explaining his topics or *topoi* as the places to which we turn for the premises of our enthymemes. Then in Chapter 3 of Book I he distinguishes the three great divisions of oratory, political, forensic or judicial, and epideictic or ceremonial, and states that he will organize his discussion of topics around this division of the kinds of oratory. This he does, and he concludes Chapter 3 just before taking up this discussion by saying:

> It is evident from what has been said that it is these three subjects, more than any others, about which the orator must be able to have propositions at his command. Now the propositions of Rhetoric are Complete Proofs, Probabilities, and Signs. Every kind of syllogism is composed of propositions, and the enthymeme is a particular kind of syllogism composed of the aforesaid propositions.

From Chapter 4 to Chapter 9 in Book I Aristotle gives the reader some practical politics designed to help the political orator in the selection of his enthymemes. In Chapter 9 he presents a discussion of virtues and vices designed to help the speaker in epideictic oratory. In Chapter 10 he turns to the topics of forensic oratory, stating: "We have next to treat of Accusation and Defence, and to enumerate and describe the ingredients of the syllogisms used therein." This dis-

cussion continues to Chapter 15, where we then are given a discussion of nonartistic proofs, with which Book I is closed.

Aristotle begins Book II by pointing out the importance of ethical and pathetical persuasion in the three types of oratory, and from Chapter 1 to 19 he gives us some practical psychology concerning human motives and emotions. It is with this that Aristotle concludes his discussion of special topics begun in Book I, Chapter 4. He then devotes Chapter 19 in Book II to general topics. It will be remembered that the distinction between special and general topics in relation to the enthymeme was made in Chapter 3 of Book I.

Upon concluding this discussion of the special and general topics from which the premises of our enthymemes must be drawn, he then in Chapter 20 of Book II takes up the study of the enthymeme in its various forms and concludes Book II in Chapter 26 with this material. Book III, of course, is devoted to style and delivery.

This view of the *Rhetoric* makes the organization of the work entirely logical and understandable. Aristotle first introduces us to the enthymeme as the element of rhetorical persuasion and gives us some preliminary definitions and classifications; secondly, he discusses the topics from which enthymemes are to be drawn, explaining that ethical, pathetical, and logical persuasion will be projected through these enthymemes depending upon our choice of propositions; and thirdly, the enthymeme is carefully analyzed in its several forms. Books I and II treat *inventio*, and Book III considers mainly *elocutio*, to a limited extent *pronunctiatio* and *dispositio*, with little or no mention being made of *memoria*. My point is that, if we view the enthymeme as the "body and substance of rhetorical persuasion," as Aristotle tells us to, we have no difficulty in understanding the organization of the *Rhetoric*. On the other hand, if the enthymeme is to be considered the instrument solely of logical proof with ethical and pathetical persuasion existing outside this concept, it is exceedingly difficult to understand the organization of the *Rhetoric*. There seems to me, however, to be no justification for this latter position except as we adopt superficial impressions which might be gotten from a failure really to analyze and understand Aristotle's system of rhetorical invention. It can be seen that the interpretation of the enthymeme here taken has important implications for the traditional conviction-persuasion dichotomy in rhetorical theory.

III. The Enthymeme as an Elided Syllogism

Thus far we have seen the enthymeme to be a syllogism drawn from probable causes and signs and have found it to be the element or unit of all reasoned discourse — ethical, pathetical, and logical. I shall now consider the question, Is the suppression of one or more propositions of a complete syllogism a necessary characteristic of the enthymeme, as is commonly held? From what I have already pointed out, we know certainly that this factor alone is inadequate to differentiate the syllogism and the enthymeme; and, on the other hand, even a casual observation of specimens of speaking and writing will show that the enthymeme appears very often in an elided form. The only question raised here, therefore, is whether or not the suppression of one or more of the propositions of a complete syllogism is *necessary* in the enthymeme.

The controversy on this particular point has been the subject of so many papers, footnotes, and comments that Hoyt H. Hudson, speaking of De Quincey's reference to the enthymeme in his *Essays on Rhetoric*, states: "At first sight the passages dealing with this subject may seem to be merely the facetious stirring up of a mare's nest . . . ." [12]

De Quincey cautions us, however:

> . . . if the question were for a name, Heaven forbid that we should disturb the peace of logicians; they might have leave to say as of Strid in Wharfdale:
>
> "It has borne that name a thousand years,
> And shall a thousand more."
>
> But whilst the name is abused, the idea perishes.[13]

Aristotle's conception of the enthymeme has, in fact, almost perished, and it is because commentators on Aristotle, and logicians and rhetoricians speaking in their own right, have persisted in defining the enthymeme merely as an elided syllogism. Facciolati, Saint-Hilaire, Sir William Hamilton, De Quincey, and others have pointed out the inadequacy of this definition, but even their grasp

[12] Hudson, Hoyt H., "De Quincey on Rhetoric and Public Speaking," *Studies in Rhetoric and Public Speaking in Honor of James Albert Winans* (The Century Company, New York, 1925), p. 141.

[13] De Quincey, Thomas, *Essays on Style, Rhetoric and Language*, edited by Fred N. Scott (Allyn and Bacon, Boston, 1893), pp. 145–146.

of the subject has not been complete, and their conclusions have not been incorporated in treatises on the subject.

I find no place in either the *Organon* or the *Rhetoric* where Aristotle defines the enthymeme as being a syllogism with one or more propositions suppressed, nor does he make this a part of any definition of the concept. It is true that he tells us in several places that a premise is *frequently* suppressed. For example in *Rhetoric* I.2 he states:

> . . . the links in the [enthymematic] chain must be few — *seldom* as many as the links in a normal chain of deductions. Thus, if one of the premises is a matter of common knowledge, the speaker *need not* mention it, since the hearer will himself supply the link.[14]

Not only does he not define the enthymeme as a truncated syllogism, but what he does say about it almost precludes the possibility that he meant to imply that the enthymeme should be so defined. The enthymeme is clearly explained as a syllogism drawn from probable causes and signs, and as such is made the element or unit of all argumentative discourse. To contend that Aristotle meant that a syllogism drawn from a probable cause or sign is not an enthymeme merely because both premises and the conclusion are expressed is in my opinion wholly inconceivable. My conclusion in this matter is that, while we may safely interpret Aristotle to mean that the enthymeme *usually* lacks one or more of the propositions of a complete syllogism, there is no justification in interpreting him to mean that this is a *necessary* characteristic of the enthymeme.

You may wonder why it is that the enthymeme as understood by Aristotle has been so largely lost when this concept occupies such an important place in Aristotle's system of rhetorical invention. I shall merely indicate some of the factors which explain this situation: (1) a lack of interest in rhetoric in the Stoic school following Aristotle, resulting in a very early confusion between logic and rhetoric, and between the syllogism and the enthymeme; (2) the persistence of this confusion in Cicero's rhetorical works, more especially in his *De Inventione;* (3) the unfortunate definitions of the enthymeme by Cicero, Quintilian, Hermogenes, and others; (4) the strange disappearance of Aristotle's *Rhetoric* during the whole of the Middle Ages and the influence of Cicero's *De Inventione* during this period; (5) the

[14] *Rhetoric*, I.2.1357ª.

mistaken interpolation in the passage in *Prior Analytics*, II.27, which made Aristotle appear to define the enthymeme as an elided syllogism; (6) the loss by rhetoric of its field of invention and the absorption of this field by logic during most of the Middle Ages; (7) the inordinate interest of the medieval scholars in the syllogism; and (8) the tendency of sixteenth- and seventeenth-century commentators on the *Rhetoric* to conform to the traditional definitions of the enthymeme.

I have discussed these factors and other matters relating to the enthymeme in some detail in another place [15] and shall not go into them here. My only purpose in this paper has been to set forth some interpretations of the Aristotelian enthymeme which seem to have escaped attention. These interpretations may be summarized in the following conclusions: (1) The enthymeme is the syllogism of rhetoric, occupying in rhetoric essentially the same place that the syllogism occupies in logic; (2) The premises of the enthymeme are probable causes and signs; (3) These premises are drawn from topics varying in specificity and exactness from the particular facts of a given case, to the most general rules of probability; (4) These premises may be phrased in language designed to affect the emotional state of the listener, to develop in the audience a confidence in the speaker, or to establish a conclusion as being a probable truth; (5) The inferential process is formally deficient in several of the enthymematic forms and many enthymemes cannot therefore be stated in valid syllogisms; (6) The enthymeme often (but not necessarily) appears with one or more of its propositions suppressed. The enthymeme for Aristotle is, in short, the practical, usable, everyday, instrument of enunciative discourse. It is universal in the field of rhetoric just as the syllogism is in Aristotelian logic, and is, in fact, the "element" or "unit" of persuasive speech. It exists wherever *reasons* are *supplied* or *implied* in discourse and is the concept which *must be understood* to appreciate the rhetorical applications of syllogistic logic.

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[15] McBurney, J. H., "The Place of the Enthymeme in Rhetorical Theory" (unpublished doctoral dissertation, University of Michigan, 1935).

THE LANGUAGE OF *TITUS ANDRONICUS*

HEREWARD T. PRICE

IN THE course of some work on an edition of *Titus Andronicus* I have come across a few interesting points of grammar and usage which have been either wrongly explained or altogether ignored in the books of reference. I should like to discuss a few of my results in this paper.

First, a word or two on the vocabulary of *Titus* in general. The Elizabethan poet had no large body of literature, handed down through many generations, to draw words from or to appeal to as an authority. He was often obliged to make up his language as he went along. Shakespeare is so much a classic that it is not always clear to us how much of his language was invented to meet the needs of the moment, or how much of it was colloquial or even provincial. There are about seventy cases where the earliest recorded instance of a word or a usage is to be found in *Titus*. There are only eight instances of obsolescent language, i.e. of words or usages not recorded in English after *Titus*. We have, besides, a number of expressions in Quarto 1 (1594) which the compositor of Folio 1 regarded as old-fashioned and changed into something more up-to-date. These will be treated below. We have also one or two alliterative phrases, such as *change of cheer* (I.i.264), *horn and hound* (I.i.494). These phrases are not learned or literary; they are from the popular poetry of the ballad, and are partly chosen for their simplicity. There are twelve reminiscences of the Bible which are sometimes difficult to recognize.[1] The vocabulary is widened by expressions and uses that are countrified or from dialect, such as *bird* = 'nestling' (II.iii.154), *coil* (III.i.225), *feed* (IV.iv.93), *honey-dew* (III.i.112), *honey-stalk* (IV.iv.91), *must* (IV.iv.46), *shive* (II.i.87), *single forth* (II.iii.69). These data show how little the Elizabethans were bound by tradition and how

[1] I.i.55, 331–332; III.i.16–22, 225, 244, 263–265; III.ii.23, 37–38; IV.i.96–97; IV.ii.32–33, 41–43; V.i.147–150. See Noble, Richmond, *Shakespeare's Biblical Knowledge* (London and New York, 1935), pp. 138–140.

much they strove for the new thing and relied upon their powers of invention. The archaisms are only occasional in *Titus*, and they must not blind us to the freshness of its style. It is important to note how Shakespeare suggests character by language. His Romans are plain and simple in speech, rising but rarely, in moments of great emotion, to heights of rhetoric or poetry. In order to stamp his personages more sharply as Roman, he brings in a large number of words with Latin associations, e.g. *continence*, *ensigns*, *obsequious*, *palliament*, *piety*, *prodigies*, *tributary*, *trophy*. Many others might be given. Some critics suppose that only a classical scholar would be capable of language so steeped in Roman sentiment. But they forget that Shakespeare occasionally blunders and writes monstrosities like *successantly* or gives to words an improper meaning, as in the case of *obsequious* (= 'having to do with a funeral'), and *palliament*, which we shall discuss below. Trained classical scholars do not make howlers of this sort.

Finally, there is Shakespeare's use of proverbs to characterize Chiron and Demetrius. These princes of the Goths are represented as rough country louts. Shakespeare indicates their oafishness by making them fond of rustic and often coarse proverbs. No other characters in the play use so many. This piece of technique is interesting as it indicates the standing of proverbs in Shakespeare's day. Gentlemen, it would appear, were already giving them up.

Before comparing the readings which the texts offer, it will be necessary to say something about the status of Quarto 1. The remarkable confusion about Alarbus in this Quarto proves that it was not printed from a prompt-book. Alarbus is murdered twice, once before the play begins and then again during Act I. Marcus speaks of the sacrifice as already carried out:

> "Fiue times he [Titus] hath returnd
> Bleeding to Rome, bearing his valiant sonnes,
> In Coffins from the field, and at this day,
> To the Monument of that *Andronicy*
> Done sacrifice of expiation,
> And slaine the Noblest prisoner of the *Gothes* . . ." (I.i.33–38).

In accordance with this speech the entrance of Alarbus is not noted. At the proper place for it the stage-directions read: "enter . . . Tamora the Queene of Gothes and her two sonnes Chiron and Demetrius." It is obvious that at this point Alarbus was not intended

to be on the stage. But later on in Act I he is hurried off the stage, where he had no right to be, in order to be slain as a sacrifice to the shadows of Titus' sons. Quarto 2 cut the knot by omitting from the speech of Marcus we have given above everything that comes after "field," leaving "In Coffins from the field" a broken line. But it does not change the stage-direction. The sort of mistake Quarto 1 makes does not usually happen in a manuscript prepared for stage-performance. Quarto 1 was therefore probably printed from Shakespeare's own manuscript. It is important to notice that the sketch of this scene, which the Marquis of Bath possesses, shows only two sons with Tamora. I shall return to this matter in my forthcoming edition of *Titus Andronicus*, where I shall also discuss the questions raised by Mr. J. S. G. Bolton in *PMLA*, XLIV (1929), 765, and by Dr. R. B. McKerrow in *Library*, New Series, XV (1934), 49.

There are a number of interesting readings in Quarto 1. Twice it has *years* for *ears* (II.iii.160; IV.iv.98). It is noteworthy that this form frequently occurs in the manuscript of Raleigh's poems. In a few cases Folio 1 normalizes the grammar of Quarto 1. At I.i.6 it substitutes *wore* for *ware* (Quarto 2, *ware*); at I.i.219, *you* for nominative *yee* (Quarto 2, *you*); at I.i.206, *wert* for subjunctive *were* (Quarto 2, *were*); at V.iii.17, *more* for *moe* with the plural (Quarto 2, *moe*). In five cases the Folio alters the grammar of Quarto 1 by making verb and nominative agree in number, e.g. for *years wants* it substitutes *years want*, and so on (II.i.26; III.i.9, 80, 226, 275). In all those instances the compositor of Folio 1 changed the grammar because he regarded it as old-fashioned.

Similar changes were made in vocabulary, that is to say, the modern or familiar word was substituted for the old-fashioned or unfamiliar word. At I.i.373 and V.i.20 the Folio substitutes *renowned* for *renowmed* of Quartos; at I.i.250, *imperiall* for *imperious;* at I.i.99 and II.iii.229, *earthly* for *earthy*.

The new information I have gleaned may be divided into the following classes:

A few instances of words earlier than anything in NED:

brave, 'brave it' (IV.i.121). Earliest in *NED* 1597.
brave = 'capital,' 'fine' (II.i.129; IV.ii.136). Earliest 1600.
bravely, 'excellently,' 'capitally,' 'well' (IV.iii.113). Earliest 1600.
empire, 'dignity or position of an emperor' (I.i.183). Earliest 1606.
obscurity, in concrete sense, 'an obscure place' (V.ii.36). Earliest 1853.

sanguine, 'red-faced' (IV.ii.97). Earliest 1680. It occurs also in Marlowe's translation of Ovid, *Elegies* (I.viii.12).
scar, verb, in a transferred sense (IV.iv.31). Earliest 1697.
single, 'to go singly'; 'to separate from others' (II.iii.69). Earliest 1616.
undone (IV.ii.77), in a mixture of senses: (*a*) 'to ruin socially' (cf. *Much Ado*, II.ii.29); (*b*) 'to ruin by seducing.' Earliest in *NED* for this is 1612, although it might have noticed *All's Well* (V.iii.147).

Senses or pronunciations not in NED:

I.i.327. *climb my palace.* Not covered by the definition in *NED.*

III.i.171. *none of both* = 'neither of the two.' Now in the dialect of Kent. Fairly frequent in the sixteenth century.

IV.iii.79. "*Titus.* Shall I have justice? What says Jupiter?
Clown. O, the gibbet maker!"

Before seeing Quarto 1, I suspected a pun here, namely, that *Jupiter* was pronounced *Jubiter*, and it turns out that this Quarto has the spelling *Jubiter* all through this scene in the Clown's speeches. The form is common in the fifteenth and sixteenth centuries. It occurs in Caxton's *Jason*, p. 1. In the play of *Narcissus* it rimes with *sheppbiter* (lines 235–236). We have the same development of *b* for *p* in *jeobardy* for *jeopardy* and in *debuty* for *deputy*.

Wrongly explained or not yet explained:

V.i.113. "almost broke my hart with extreame laughter."
This means simply 'to die.' It occurs again in Marlowe's *Massacre at Paris*, l. 557.

IV.iv.93. "words more sweet and yet more dangerous,
Then baites to fish, or honniestalkes to sheepe,
When as the one is wounded with the bait,
The other rotted with delicious feede."

NED explains *feed* as 'food (for cattle); fodder, provender.' I think it is far more likely to be the sense 'pasturage, pasture; green crops' ("honniestalkes").

A few changes of special interest:

IV.i.101. Quarto 1 reads: "You are a young huntsman Marcus, let alone." Folio 1 reads *let it alone*. *Let it* might be pronounced *let*; the Folio is simply replacing the spelling at the expense of the metre.
Compare *Winter's Tale*, II.i.18, "Who taught 'this?" and Furness' note in his Variorum edition. Compare especially *ibid.*, II.ii.63, where *let it* is spelt *le't*.

IV.i.129. "Reuenge the heauens for olde Andronicus."
Folio 1 makes obvious correction, *ye Heavens*. This gives a stronger line and *the* in Quarto 1 can be easily explained as a misinterpretation of *ye*. But *the Heavens* is not impossible; it occurs in Marlowe, *Massacre at Paris*, line 177:

"The Heavens forbid Your Highness such mishap." On the principle that the harder reading is to be preferred Quarto 1 may stand.

II.i.69. Quarto 1 reads:

> "Young Lords beware, and should the Empresse know,
> This discords ground, the musicke would not please."

Folio 1 and all subsequent editions read *an should*. In my opinion *an should* is an impossible construction. I have been unable to find it anywhere else. It is the mistake of a careless compositor. *And* would make excellent sense; it is emphatic and means: "and let me tell you this." This emphatic use of *and* is a characteristic of Aaron's style. In the same speech at line 63 Aaron says:

> "Why lords, *and* think you not how dangerous
> It is to jet upon a prince's right?"

II.iv.15. Quartos 2, 3, and Folio 1 substitute "slumber in eternal sleep" for "slumber an eternall sleepe" of Quarto 1. Probably the compositor is normalizing here too. The reading of Quarto 1 is quite possible. Compare "thy sister sleeps A long, Longe slumber" (Charlemagne, II.i.464–465).

III.i.125. Quarto 1 reads: "How they are staind like meadowes yet not drie." Quarto 2, Folio 1, etc., read *in* for *like*. Collier conjectured *as*, just missing the right reading by a hair's breadth.

IV.iv.40. Quarto 1 reads: "Yea forsooth & your Mistriship be Emperiall." Quarto 2 and all subsequent texts read *Mistership*. I think they are quite wrong. The Clown is speaking to the Empress, and he gives her the same title, *mistressship*, that he would have given to any farmer's wife. That is the whole joke. To make him say *mistership*, as if he thought the Empress were a man, is quite unnecessary. It is not so much of a joke as the other word.

V.i.27. *tawny*. "Peace tawnie slave, halfe me, and halfe thy Dame."

On this Herford's note is: "*tawny*, i.e. a hue between black and white. This is in palpable contradiction with one previous statement that the Moor's child is a 'blackamoor'" (Eversley ed., 1900). It is true that the child is repeatedly called *black* (IV.ii.66, 99, 120, etc.), and it is here called *tawny*. We must start out from the Elizabethan belief that the children of a black father and a white mother were always black (R. Scot, *Discoverie of Witchcraft*, p. 312). Aaron's child was meant to have the same colour as his father. *Tawny* is frequently applied in Elizabethan English to people who are indubitably black. Thus in *Lust's Dominion* the Moor says of himself, "Although my flesh be tawny" (I.ii), and yet the play is full of references to his blackness.

In H. Holland's *Pancharis* we have the following lines:

> "Why should a lady like with all her hart
> (Her selfe borne under Jove and Venus just)
> A tawny face befur'd with sable haire,
> Borne under old Saturnus starre combust? . . .
> It is because that in faire woman's eyes
> Blacke men seem pearles.
> Or is it haply this
> That any beauty layde against the blacke
> Of much more beautie and more brightnes is?"
>
> — J. Payne Collier, *Illustrations of Old English Literature* (1861), 11.49.

Another writer speaks of a "Tawnye Negro, or Barbarian Moore" (R. C., *Times' Whistle* [1616], III.403). We probably have to do with a poetical use of the word *tawny* Or we may have another example of the Elizabethan haziness in the use of words relating to colour. If they had anything definite in mind, it would probably be the fashionable colour of ladies' stockings in London ten years ago which was called *nigger*. I was authoritatively informed that this meant the darkest shade of brown. Shakespeare uses the word again in the *Merchant of Venice* in the opening stage direction of II.i: "Enter Morochus a tawnie Moore all in white." There is no doubt this man is black. And again he makes Philo apply the word to Cleopatra (*A. and C.*, I.i.6). There is plenty of evidence to show that the Elizabethans believed that the Egyptians were black, but Shakespeare no doubt intended only to indicate Philo's savage contempt for Cleopatra. In his speech the word is simply a term of abuse.

Dame. In the line given above (V.i.27) Quarto 1 reads *Dame;* Quarto 2 and all other editions read *Dam.* Shakespeare uses *dame* for a human mother in *Lucrece* (line 1477), and he probably meant it here; although *dame* might plausibly be explained as a misreading of *dame.* On the principle that what makes sense must stand, especially when supported by other passages in Shakespeare, *dame* ought to supplant *dam* in modern editions. It is, with the passage from *Lucrece,* the latest example of *dame* = 'human mother' in English. Notice how the passage in *Lucrece* supports Shakespeare's authorship of this passage in *Titus,* at any rate.

palliament. This word occurs only twice in English literature, and it has never been properly explained. It occurs first in Peele's *Order of the Garter:*

> "Anon I saw . . .
> A goodly king in robes most richly dight,
> The upper like a Roman palliament,
> Indeed a chaperon, for such it was;
> And looking nearer . . .
> An ancient badge of honour I espied,
> A garter brightly glittering in mine eye . . . " (lines 87–97).

The context makes it quite certain that Peele is referring to the robes of the Knights of the Garter, which in those days were purple. Peele says in effect that Edward III in his purple robes of the Garter was like a Roman Emperor wearing the purple. In the same poem Peele has the following passage:

> "O sacred loyalty in purest hearts
> Thou build'st thy bower! Thy weeds of spotless white,
> Like those that stood for Rome's great offices,
> Make thee renown'd, glorious in innocency . . . " (lines 313–317).

Here there is an obvious reference to the white gown of the *candidatus*, the candidate for office in Rome.

Now *Titus* has the following passage:

> "*Titus Andronicus*, the people of Rome,
> Whose friend in iustice thou hast euer beene,
> Send thee by mee their Tribune and their trust,
> This Palliament of white and spotles hue . . .
> And name thee in election for the Empire . . .
> Be *Candidatus* then, and put it on . . . " (I.179–185).

Here the palliament is obviously white. What has happened is quite clear. Shakespeare had read Peele's poem on the garter and had got the two passages mixed up in his memory. There remained in his mind vague recollections of a Roman garment called *palliament* and of Roman weeds that were spotless white. He combined the two. This may seem impossible, but every commentator on this passage has done the same thing — they all declare that *palliament* in Peele and Shakespeare alike means a white garment. The *NED* is the more inclined to do so, because it dates *Titus* 1588 and Peele's poem 1593. For the *NED Titus* has the priority and determines the sense. However, there cannot be the slightest doubt that the garment Peele had in mind was the red robe of the Knights of the Garter. The word *chaperon* makes it indisputable. *Chaperon* is a word for the hood of the garter robes.

The passage is extremely important in two respects. It shows how Shakespeare's memory worked. We see, also, with what consummate impudence he borrowed Roman-sounding words from his contemporaries in order to create a Roman atmosphere in his play. Further, it quite puts Peele out of the running as author or part author of *Titus*. Peele would not misquote himself, nor would he allow this mistake to stand in any play in which he had a hand.

Since writing this paper I have discovered that Bacon distinguishes clearly between *black* and *tawny* (*Sylva*, §399). But my conclusion remains that they were confused by the poets.

I should like to take this opportunity to express my thanks to Professor J. Q. Adams of the Folger Library, Washington, for so kindly allowing me to quote Quarto 1.

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ADDISON'S THEORY OF THE IMAGINATION AS "PERCEPTIVE RESPONSE"

CLARENCE DEWITT THORPE

WRITING in the *Dictionary of National Biography*, many years ago, Leslie Stephen summarily disposed of Addison as a critic, and in so doing expressed with fair accuracy the majority opinion of the nineteenth century. "Addison's critical doctrines are obsolete," he declared tersely, and proceeded briefly to show why the one-time acclaimed Augustan authority might now be safely disregarded. A later view is, however, rapidly superseding this disrepute into which Addison had fallen. Mr. Basil Worsfold may be given credit for reopening the case for Addison, when he calls him the first genuine English critic, who "did for criticism what Descartes did for philosophy." [1] Since then, among others who have spoken for Addison, though more guardedly than has Worsfold, are J. G. Robertson and E. F. Carritt. Professor Robertson claims for Addison the beginning of a new aesthetics in England. He was the first Englishman to conceive of the imagination as the basis of poetry, Robertson declares. "It is not too much to say that in the suggestive papers on the Imagination Addison laid the foundation of the whole Romantic aesthetics in England." [2] Professor Carritt traces Kant's chief aesthetic ideas back to Addison, and to his successor Hutcheson. From Addison, particularly, Kant got his ideas of the sublime. Concluding a comparison of Kant and Addison relative to the most valid elements in Kant's theory Carritt says, "All is Addison's except the style." [3] So it turns out that Addison as a critic is again a figure of interest, and is again being closely studied.

There is ample justification for this renewed attention. For Addison stands in a peculiarly close relationship to later Romantic critics and to those of our own day who are interested in discovering

[1] *The Principles of Criticism* (George Allen, London, 1897), Chap. V.
[2] *The Genesis of the Romantic Theory in England* (Cambridge, 1923), p. 241.
[3] "Effects in England of Kant's Philosophy," *The Monist*, 25: 313 ff.

scientific standards in criticism. In his essay on the imagination he made the most ambitious attempt up to his time to relate scientific psychology to aesthetic problems, hence to found critical theory on a sound basis of the relationship of art to mental processes.

Very early in *The Spectator* papers, over a year before the papers on the imagination, Addison had enunciated a principle of taste:

> . . . for it is impossible that anything should be universally tasted and approved by a Multitude, tho' they are only the Rabble of a Nation, which hath not in it some peculiar aptness to please and gratifie the Mind of Man (No. 70, May 21, 1711).

Here is the criterion of universal appeal. "Human Nature," continues Addison, "is the same in all reasonable Creatures; and whatever falls in with it, will meet with admirers amongst Readers of all Qualities and Conditions."

In *The Spectator*, No. 409, printed two days before the opening paper on the imagination, Addison offers a definition of taste, raises the question whether taste can be cultivated, and suggests the necessity of discovering some fundamental principle rather than applying mechanical rules for forming judgments in literature. "I think I may define it to be that Faculty of the Soul, which discerns the Beauties of an Author with Pleasure, and the Imperfections with Dislike," Addison writes. This faculty "must in some degree be born with us." Some "who have other Qualities in Perfection are wholly void of this." Those who have native taste must develop it. Critics stand in peculiar need of a developed taste:

> I must confess that I could wish there were Authors of this kind who beside the Mechanical Rules which a Man of very little Taste may discourse upon, would enter into the very Spirit and Soul of fine Writing, and show us the several Sources of that Pleasure which rises in the Mind upon the perusal of a noble Work.

In looking for these sources of pleasure we must recognize that the Rules, however useful, are merely incidental:

> Thus, altho' in Poetry it be absolutely necessary that the Unities of Time, Place, and Action, with other Points of the same Nature, should be thoroughly explained and understood, there is still something more essential to the Art that elevates and astonishes the Fancy, and gives a Greatness of Mind to the Reader, which few of the Criticks besides *Longinus* have considered.

Addison's study of the imagination is an attempt to discover this "something more essential" to art than the Rules can explain. He

proposes, he writes, to enter upon an "Essay on the Pleasures of the Imagination, which though it shall consider the Subject at large, will perhaps suggest to the Reader what it is that gives a Beauty to many Passages of the finest Writers both in Prose and Verse."

Thus Addison delimits the problem he is to attack in the forthcoming papers. He has clearly committed himself to an attempt to consider the psychological bases of beauty. For if he is to explain the experience of beauty he must begin with a recognition that a certain type of mental activity or reaction commonly called "beauty" exists, and he is bound to try to analyze the nature of this activity or reaction, to define and analyze its causes, and to discover how these causes produce their effects.

He accordingly sets himself to answer the specific questions implicit in his problem: What objects in the external world arouse the aesthetic, or imaginative, experience? What objects in art arouse it? How do they arouse it? In other words, what in the Constitution of our minds makes this pleasant experience possible? What is the nature of this experience: How is the mind affected; how does it respond?

Addison begins his analysis with the hypothesis that there are two ways to see things in the external world, one the imaginative, the other the non-imaginative. "Pleasures of the Imagination" are primary and secondary. "Pleasures of the Primary Imagination" are such as occur in the presence of beautiful or great or novel objects in nature, or of works of architecture. "Pleasures of the Secondary Imagination" are those which are aroused by literature and other representative arts.[4] It is not given to everyone to experience

[4] As he originally conceived his project, Addison planned to give chief attention to the "Primary Imagination." This is made clear from a brief passage in the notebook version of the essay: "We have already considered the first Division [the 'Primary Imagination'], and shall therefore have no occasion to stay long upon the second, which has, as we shall see, so great dependence on the former" (Campbell, J. D., *Some Portions of Essays Contributed to the Spectator by Mr. Joseph Addison* [Glasgow, 1864]). This was quite changed in the second draft, where the sentence reads: "We have already considered the first Division, and shall therefore enter on the other, which, for Distinction sake, I have called the Secondary Pleasures of the Imagination" (*The Spectator*, No. 416). The reason for the change can easily be surmised. In first considering his problem Addison obviously intended to emphasize the things in nature which strike upon the imagination. By the time he reworked his material for *The Spectator*, however, his interest was in adapting the principles of imaginative response to literary criticism. Once he had entered upon this second phase of his subject, he found it

these pleasures, at least to their full extent. Such good fortune is reserved for the man of imagination. "A Man of a Polite Imagination is let into a great many Pleasures, that the Vulgar are not capable of receiving." The pleasure Addison is talking of here is what we characterize today as aesthetic pleasure. The faculty by which this pleasure is received is the imagination. The function of the imagination in such activity is what I have ventured to designate as "perceptive response."

It should be explained, before we proceed further, that, though at the outset of his inquiry this function of the imagination is Addison's main concern, before he is through he has considered the imagination both as an agency of creative perception and as a selective, forming faculty in the production of art. The first of these was an adaptation of Locke's explanation of the secondary qualities of matter.[5] The second was an adoption with variations, of the Baconian theory of ideal imitation.[6] Neither one is so peculiar or so fundamental to Addison's thesis, however, as his idea of the imagination as the organ of taste and perceptive response. I shall, therefore, in the pages that follow, limit myself to an examination of this phase of his theory, with some attempt to indicate the psychological bases upon which he built and the sources from which he seems to have drawn.[7]

Addison nowhere in the essay gives a precise definition of his term "Imagination." He makes statements about it, tells what acts

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growing under his hand; before he was through, it had run into six essays, as against five, including the introductory paper, in the first division. Much of this obviously came from second thought. The latter part of the essay is radically enlarged and altered from the original draft, additions including considerable parts of Nos. 416 and 417, much of 418, all of 419, nearly all of 420, and parts of 421. How much the complexion of the essay is changed by these additions may be inferred from the fact that new parts of 418 and the entirely new 419 (on *The Fairy Way of Writing*) contained most of what Addison had to say on the effects of the tragic and on the creative power of the imagination, and that the new material in No. 420 covers Addison's most important pronouncements on the sublime, the passages in which Professor Carritt finds the origin of Kant's ideas of sublimity. As was the case in the criticism of *Paradise Lost*, some of Addison's best and most individual ideas seem to have come after more mature reflection, when, launched upon his project, he saw new meanings and implications opening up before him, and, in the warmth of creative thought, dared to be original.

[5] *The Spectator*, No. 412.

[6] *Ibid.*, Nos. 418, 419.

[7] This paper is a part of a longer study, in which I am including an examination of Addison's theory of the constructive functions of the imagination.

upon it, describes the effects of such action, identifies it with fancy; but he does not definitely state its genus and differentiae. Two years after the paper on the imagination he tells us, in a statement remarkable for the time, that the soul is a unity, that our manner of considering the memory, understanding, will, and imagination as separate faculties is a mere matter of convenience, since "there is no such Division in the Soul it self," for "it is the whole Soul that remembers, understands, wills, or imagines." [8] To speak of an act of imagination, then, would merely indicate that the soul as a unit was performing in a certain way. The faculty psychology is thus done away with at one stroke, and it simply remains to distinguish between imaginative, volitional, and other types of mental activity. Such a view would at once remove any obligation to define faculties of mind, and, if we could believe that Addison had arrived at this position by the time he wrote the papers on the imagination, would greatly simplify our immediate problem. Quite clearly in these papers, however, Addison is still talking in terms of separate faculties. The words "Imagination" and "Fancy" he uses interchangeably, but he makes a studied distinction between the imagination and the understanding, and sets "Memory" and "Sense" apart from either. The burden of definition then still remains.

We find help in arriving at Addison's meaning in the first paper. "The Pleasures of Imagination, taken in the full extent," he says, "are not so gross as those of Sense, nor so refined as those of the Understanding." This gives the imagination an intermediate place between sense perception and whatever intellectual acts would be comprehended under understanding. Furthermore, the pleasures of the imagination, we are told, are easier to be acquired than those of the understanding. We but open our eye, and the scene enters, the colors are painted on the fancy. Little attention or application of mind is required; the effect is immediate, automatic, requiring exercise of neither will nor reason: "We are struck, we know not how, with the Symmetry of any thing we see, and immediately assent to the Beauty of an Object, without enquiring into the particular Causes and Occasions of it." This implies a faculty of mind once removed from sense which receives its impressions with the same immediacy as sense, but whose perceptions involve the element of pleasure, in spontaneous recognitions of certain elements in its objects.

[8] *The Spectator*, No. 600, Sept. 29, 1715.

We learn, moreover, that the imagination is the picture-making faculty. It is that part of our nervous organization which receives and preserves images or varies or compounds its materials into new images. The mind of man is so constituted that it takes pleasure in these constructions:

> . . . so that by the Pleasures of the Imagination or Fancy (which I shall use promiscuously) I here mean such as arise from visible Objects, either when we have them actually in our View, or when we call up their Ideas into our Minds by Paintings, Statues, Descriptions, or any the like Occasion. We cannot indeed have a single Image in the Fancy that did not make its first Entrance through the Sight; but we have the Power of retaining, altering and compounding those Images, which we have once received, into all the Varieties of Picture and Vision that are most agreeable to the Imagination; for by this Faculty a Man in a Dungeon is capable of entertaining himself with Scenes and Landskips more beautiful than any that can be found in the whole Compass of Nature.[9]

Literature is in general delightful in proportion as it has power to present images. History and science likewise may become the subject of imaginative pleasure if the writer has the talent and judgment to present his matter pictorially. Thus Livy describes everything

> . . . in so lively a Manner, that his whole History is an admirable Picture, and touches on such proper Circumstances in every Story, that this Reader becomes a kind of Spectator, and feels in himself all the variety of Passions which are correspondent to the several Parts of the Relation.[10]

It is true that the pleasures Addison attributes to nature and the arts, including literature, are not always clearly distinguished from religious and rational elements; even so we can safely say that, so far as we find it described in its purer form, imaginative pleasure with Addison is basically related to the picture-making function of mind.

The characteristic of this pleasure is a sort of nervous excitation, a state of heightened awareness in emotional apprehension. In the presence of agreeable objects the man with a good imagination finds himself toned up spiritually and physically; his "Animal Spirits" are set in "pleasing and agreeable Motion"; any tendency to grief and melancholy is dispersed; his soul is renewed in a sense of inner needs gratified.[11] If the object of his view is vast and stupendous he is "flung into a pleasing Astonishment at such unbounded Views," and he feels "a delightful Stilness and Amazement in the Soul at

[9] *The Spectator*, No. 411. [10] *Ibid.*, No. 420. [11] *Ibid.*, No. 411.

the Apprehension of them."[12] If, in addition, the object is new or uncommon "it fills the soul with an agreeable Surprise, gratifies its Curiosity, and gives it an idea of which it was not before possessed. . . . It serves us for a kind of Refreshment, and takes off from Satiety . . . ."[13] But Beauty is the crowning quality of all, for "there is nothing that makes its way more directly to the Soul than Beauty, which immediately diffuses a secret Satisfaction and Complacency through the Imagination, and gives a Finishing to anything that is Great or Uncommon."[14]

It will be seen that, in harmony with his idea that the imagination lies midway between sense and understanding, Addison's "Pleasures of the Imagination" are almost as much an affair of body as of spirit. When the mind is presented with the corporeal, concrete form of those objects fitted to excite aesthetic feeling, physical is intermingled with purely mental response in indistinguishable union. This helps identify Addison's view, in respects, with modern theories of aesthetic pleasure as essentially the response of an organism to external stimuli, and with the "new philosophy" which had preceded him, so far as it sought a mechanical explanation for emotional effects. Indeed, Addison's theory bears remarkably close relationship to certain phases of the psychology of Hobbes, Descartes, and Locke, and can be best understood through reference to their discoveries. I wish, therefore, to devote much of the rest of this paper to a brief examination of some of the ideas of Hobbes, Descartes, and Locke for the nature and extent of possible influences upon Addison in developing his basic theory.

Scott-James declares that, in his conception of imagination, Addison merely went to Locke and Hobbes and took over his idea ready-made. He then quotes Hobbes' statement for imagination as memory to indicate the origin of Addison's idea. And, adds that critic in disdainful accents, "decaying sense is a pretty poor substitute for the processes of the creative imagination."[15] But one will look long in Hobbes for an equivalent to the imagination here described. Imagination, with Hobbes, is different things at different times. It, or what Hobbes on occasion makes its equivalent, fancy,

[12] *Ibid.*, No. 412.
[13] *Ibid.* [14] *Ibid.*
[15] Scott-James, P. A., *The Making of Literature* (Henry Holt and Company, New York, 1929), p. 151.

is original perception;[16] it is retained imagery or memory;[17] it is compounded imagery;[18] it is a faculty which selects and brings together materials from the whole field of experience, to form, with the aid of judgment, new combinations;[19] it even seems, upon occasion, to be Wit.[20] But of the imagination as an instrument of a special perceptive process involving pleasurable response, Hobbes had only a faint conception. Mr. Scott-James' naïve, uninformed judgment that Addison does little more than borrow the Hobbes theory of imagination as memory is so untenable as to be almost incredible.

It is true that from Hobbes Addison probably derived much, both directly and indirectly. He knew Hobbes well, wrote of him with approval, sometimes echoed his phrases. He undoubtedly got from Hobbes some very important ideas and suggestions. The most obvious of these are to be found in Hobbes' speculations upon the problem of pleasure and pain.

Hobbes goes further in an analysis of the phenomena of pleasure and pain than had anyone up to his time. Though the application of his findings is only incidental — for his primary aim was not to analyze artistic processes — his ultimate achievement was to lay a firm foundation for a psychology of aesthetic response. Hobbes associates pleasure and pain (other than the kind that proceeds immediately from sense impression) with the passions. His approach is essentially physiological. Pleasure and pain are the result of motions to the heart. The effects of a quickening of vital motion induced by motion of sense are pleasure and, hence, appetite; but the effects of a slackening or a hindering of vital motion are pain and aversion.[21] The appetites and aversions constitute our passions. The passions, then, are inseparably linked with perceptions of pleasure and pain: " . . . all appetite, desire and love, is accompanied

[16] *Leviathan*, Part I, Chap. i; in *The English Works of Thomas Hobbes*, collected and edited by Sir William Molesworth, (John Bohn, London, 1839), III : 2. This edition is hereafter referred to in this article as "Molesworth."

[17] *Ibid.*, I, ii; in Molesworth, III : 4–6.

[18] *Ibid.*, I, ii; in Molesworth, III : 7.

[19] Spingarn, J. E., "Answer to Davenant" and "Virtues of an Heroic Poem," *Critical Essays of the Seventeenth Century*, II : 59–60.

[20] *Leviathan*, I, viii; in Molesworth, III : 56–60.

[21] *The Elements of Philosophy*, in Molesworth, I : 406; *The Elements of Law*, edited by Ferdinand Tönnies (Cambridge, At the University Press, 1928), I, vii : 22.

with some delight more or less; and all hatred and aversion with more or less displeasure and offence." [22]

The passions, once established, may be the originators of action. A happy life is characterized by lively appetites and eager "motion toward." [23] The elemental pleasurable and negative responses are, however, more nearly the product of passive reception. Hobbes at one point ascribes the sensations of pleasure and pain to an additional sense, the result of mechanical motion from without upon the nerves and muscles of the heart. "But there is another kind of sense, of which I will say something in this place, namely, the sense of pleasure and pain, proceeding not from the reaction of the heart outwards, but from continual action from the outermost part of the organ towards the heart." [24] Such a statement could hardly have escaped the attentive eye of Addison, and may well have reinforced ideas derived from Locke and Descartes of an internal sense or faculty having to do with effects of pleasure and pain.

Scattered through Hobbes' writings are many passages bearing upon the nature of aesthetic pleasure and its causes. He discusses the delight to be had from novelty and the consequent satisfaction of curiosity, analyzes the sources and the peculiar quality of laughter, inquires into the pleasure which lies in the painful and tragic and in the elevated language and stirring events of a heroic poem. Hobbes does not, however, ascribe these pleasures, as does Addison, to the imagination. He occasionally uses the term "Pleasures of the Mind," [25] which admittedly may have helped Addison in formulating his phrase. In one place he even uses the almost identical "pleasures in the imagination." [26] His meaning, here, however, is limited to pleasures which are enjoyed in anticipation, such as the imagination of fame after death.[27] Hobbes' service to Addison, then, so far as the imagination as perceptive response is concerned, was

[22] *Leviathan*, in Molesworth, III : 42. [23] *Elements of Law*, I, x : 22.
[24] *The Elements of Philosophy*, in Molesworth, I : 406.
[25] See *Leviathan*, I, vi, in Molesworth, III : 43.
[26] *Ibid.*, I, xi, in Molesworth, III : 87.
[27] Perhaps one of the nearest approaches to Addison's idea of the imagination as perceptive response occurs in *The Whole Art of Rhetoric*, Chapter IX, where Hobbes at least suggests a pleasure in images formed in the imagination:

"Forasmuch as there is nothing more delightful to a man, than to find that he apprehends and learns easily; it necessarily follows, that those *words* are most grateful to the ear, that make a man seem to see before his eyes the things signified" (Molesworth, VI : 496).

to help open up to him the whole problem of pleasurable response, to suggest to him something of a method of approach, and to furnish certain important elements for his theory. But Addison in no wise found his theory ready-made in Hobbes.

His debts to Locke and Descartes are quite as great, if not greater, and are at points even more direct. The Sheldonian oration suggests that it was Descartes as much as anyone who taught Addison the virtues of honest doubt. Descartes, it will be recalled, held "That in order to seek truth, it is necessary once in the course of our life to doubt as far as possible of all things." [28] This note constantly recurs in Descartes' writing. Locke in turn taught the virtues of release from authority in an unprejudiced search for truth. "This I am certain," he says, "I have not made it my business either to quit or follow any authority in the ensuing discourse: truth has been my only aim, and wherever that has appeared to lead, my thoughts have impartially followed, without minding whether the footsteps of any other lay that way or not." [29]

Locke's constant insistence that the way to all real knowledge is experience, that there are causes for all mental effects if we can but find them, and that the way to discovery is through the empirical method of introspection can hardly have failed to shape Addison's approach to his study of the pleasures of the imagination. One would suspect this even were there no evidence of definite influence through Addison's own testimony. For example, the following might be taken as the major premise for Addison's reasoning on the imagination:

> . . . Now . . . pleasure and pain are produced in us by the operation of certain objects, either on our minds or our bodies, and in different degrees. . . .[30]

[28] *The Principles of Philosophy*, opening statement.

[29] Under the heading "Men must think and know for themselves," *Of Human Understanding*, Book I, Chap. iv, Sec. 23. (I am using the Bohn edition of Locke.) Again Locke (*ibid.*) writes: "Not that I want a due respect to other men's opinions; but after all the greatest reverence is due to truth: and I hope it will not be thought arrogance to say, that perhaps we should make greater progress in the discovery of rational and contemplative knowledge, if we sought it in the fountain, in the consideration of things themselves, and made use rather of our own thoughts than other mens to find it, for I think we may as rationally hope to see with other men's eyes, as to know by other men's understanding." Here is a passage that might well have been placed as a motto over the essay on the Imagination. For much as he is here indebted to others for both general and particular ideas, Addison is in the end searching out for himself a new explanation of taste and the phenomena of aesthetic pleasure.

[30] *Op. cit.*, II, xx, Sec. 41.

There are other passages in Locke which strongly suggest influence on Addison in his speculations. Discussing the "modes of pleasure and pain," [31] Locke points out that, just as in the body there is bare sensation in itself, or "sensation accompanied with pain or pleasure; so the thought or perception of the mind is simply so, or else accompanied also with pleasure or pain, delight or trouble, call it how you please." Paraphrasing Hobbes,[32] Locke goes on to show how such accompaniments become associated with our ideas of good and evil. These moral implications, however, are of small concern here. What is important is the suggestion for investigating these sensations, which Locke holds can be neither described nor defined, and can be known only through introspection. "Pleasure and pain and that which causes them . . . are the hinges on which our passions turn: *and if we reflect on ourselves and observe how these, under various considerations, operate in us; what modifications or tempers of mind, what internal sensations* (if I may so call them) *they produce in us,* we may thence form to ourselves the ideas of our passions." [33] This is a springboard from which Addison could have taken off. For, as we have seen, Addison addressed himself definitely to a phase of the problem here stated: of defining, through reflecting on the mind itself, the peculiar internal sensations of pleasure which attend our perception of agreeable objects in nature and art.

Moreover, though Locke in general shows a fundamental distrust of the imagination [34] (or fancy — he uses the terms interchangeably),

[31] *Ibid.*, II, xx, Sec. 1.

[32] *Ibid.*, I, vii, Sec. 3.

[33] *Ibid.*, II, xx, Sec. 3. The italics are mine.

[34] Locke's conception of imaginative literature is not a flattering one. Grudgingly, in a passage made up of nicely weighed concessions and negations, he admits certain claims to literature purely on the basis of its power to give delight and the tendency of men to demand that which pleases them. "Since wit and fancy find easier entertainment in the world than dry truth and real knowledge, figurative speeches and allusions in language will hardly be admitted as an imperfection or abuse of it" (*Of Human Understanding,* III, x, Sec. 34). Locke appears to have rejected quite definitely the traditional neo-classic theory of the value of art in teaching. On the contrary, he sharply distinguishes discourse designed to present truth from "eloquence," which is of use only to entertain, to be avoided wherever the intention is to inform or instruct. (In contrast with Hobbes, who related the quick ranging of mind which is joined with curiosity, and the desire to learn in general, with a good wit, which comprehends both judgment and fancy [*The Elements of Law,* I, x, Sec. 4].) "All the art of rhetoric — all the artificial and figurative application of words" to be found in eloquence "are for nothing else but to insinuate wrong ideas, move the passions, and thereby

he nevertheless recognizes that works of imagination give a pleasure distinct from and more universal than those of reason. Locke does little to explain this pleasure, his remarks to the point proving upon examination to be the merest generalizations. Even so they contain phrases from which Addison may have derived fruitful suggestions for parts of his theory. For here we find, at least implied, two basic elements of Addisonian view: first, aesthetic pleasure from works of wit (fancy or imagination) are assigned to the fancy (imagination) itself; second, the "beauty" of such works is immediate and effortless, involving the intervention of neither will nor reason. It is the function of wit, Locke writes, in his explanation of the difference between wit and judgment, to put together with quickness and variety ideas in which it finds resemblance or congruity, "thereby to make up pleasant pictures and agreeable visions in the fancy." Again, he speaks of metaphor and allusion as making up so large a part of the pleasantry of wit, "which strikes so lively on the fancy, and therefore is so acceptable to all people." This is true, he goes on

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mislead the judgment, and so indeed are perfect cheats" (III, x, Sec. 34). Locke can only observe with regret that the universal fondness for such arts of fallacy shows "how little the preservation and improvement of truth and knowledge is the care and concern of mankind." With the general preference against him, Locke quite realizes the futility of resistance, however, and admits as much. "I doubt not but it will be thought great boldness if not brutality in me, to have said this much against it," he writes (*ibid.*). "Eloquence, like the fair sex, has too prevailing beauties in it to suffer itself ever to be spoken against; and it is in vain to find fault with those arts of deceiving, wherein men find pleasure to be deceived." (Locke's terms for the arts he here reprobates are "rhetoric" and "eloquence," with only a general reference to "wit" and "fancy." There can be little doubt, however, that he had in mind all fictitious as well as ornamental discourse.)

It is hardly to be surmised that a man with so low an opinion of the literary arts would hold the imagination in great esteem. Granting full credit to the constructive powers of the mind in forming complex ideas, he nevertheless makes a distinction between complex ideas that are real and ideas that are imaginary, or, to use another term, fantastical. "Fantastical or chimerical, I call such ideas as have no foundation in nature," he explains (II, xxx, Sec. 1). Dreams and fancies are thus constantly set off, at least by implication, from the realities of things. Alert to the fact that his argument that knowledge is only the perception of the agreement or disagreement of our own ideas will lay him open to the charge of espousing a theory that fails to distinguish between the false and the true, between the visions of the enthusiast and the reasonings of the wise, he sets out to show that "this way of certainty by the knowledge of our own ideas, goes a little further than bare imagination" (IV, iv, Secs. 2 3). Simple ideas from actual objects, either derived through sense while the object is present, or through memory if the object is absent or past, form the material for true knowledge. The mind must ever be on guard against the semblances which fancy adds to

to say, "because its beauty appears at first sight, and there is required no labor of thought to examine what truth or reason there is in it. The mind, without looking any further, rests satisfied with the agreeableness of the picture and the gaity of the *fancy* . . . ." [35]

Addison made considerable use of the passage in which these statements occur in his papers on Wit (specifically *The Spectator*, No. 62); and his expression of the immediacy of the appeal of beauty in *The Spectator*, No. 411, cited earlier in this article, sounds much like a paraphrase of Locke. There can be small question of Locke's influence. Yet Locke's failure to develop his leads or to make application of them leaves him in the position of one who, almost by chance, has thrown out ideas the importance of which he fails to grasp or in which he has too little interest to stimulate him to proceed to conclusions. It remained for Addison to perceive their implications and to utilize them in developing a more complete aesthetic theory.

It should be noted, too, that Addison's view of the imagination

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ideas, however: "There are so many ways of fallacy, such arts of giving colours, appearances, and resemblances by their court-dresser, the fancy, that he who is not wary to admit nothing but truth itself . . . cannot but be caught" (*Of the Conduct of the Human Understanding*, Sec. 33 [Bohn, I: 89]).

It is true that Locke admits one form of authentic ideal construction which he clearly designates as imaginative. This is the complex idea, discussed under the head "Mixed Modes" (*Of Human Understanding*, III, v), which, since it precedes the actual experience, originates wholly in the mind. Thus, before men knew the *things*, they had *ideas* of incest, murder, and treason. Adam's invention of the terms "kinneah" and "niouph" will illustrate the principle (III, vi, Secs. 44–47). Adam observes the melancholy of Lamech and *imagines* it to arise from a suspicion he has that his wife Adah has too great kindness for the man. In expressing his suspicions to Eve he makes use of the two new words "kinneah" and "niouph," the one standing for suspicion in a husband of his wife's disloyalty, the other for the act of committing disloyalty. The event proves that Adam's suspicions were without basis, but the ideas he had formed were none the less adequate. The word "kinneah," for example, was a combination of simple ideas, which Adam, "without regard to any archetype, without respect to anything as a pattern, voluntarily put together, abstracted, and gave the name kinneah to, to express in short to others, by that one sound, all the simple ideas contained and united in that complex one. . . . His own choice having made that combination, it had all in it that he intended it should, and so could not but be perfect, could not but be adequate . . ." (III, vi, Sec. 44). This process of forming and naming ideas Locke considers quite different from the marking and naming of substances — as of the hard, glittering, yellowish substance brought to Adam by one of his children, to which he applied the term "zahab." In the first case, Adam "puts ideas together only by his own imagination"; in the other, he uses ideas from actual existence. Yet one is as valid as the other (III, vi, Secs. 44–46).

[35] *Of Human Understanding*, II, xi, Sec. 2.

differs in important particulars from Locke's. Where Locke derogates, Addison dignifies, the imagination;[36] where Locke connects the imagination with a certain type of ideas of reflection, very likely false, Addison regards it primarily as a picture-receiving, picture-retaining, picture-building faculty, inseparably related to aesthetic response. Let us recall, too, that with Addison the imagination lies midway between sense and understanding, in its activities less gross than sense, less refined than understanding — an idea not to be found in Locke. Some of these modifications in Addison's conception may, no doubt, be attributed to his own thinking; others may be traced to Hobbes; still others, and very important ones, as we shall see presently, to Descartes, whose theory, embodying as it does some of the best ideas in medieval psychology, with certain unique additions, contained much for Addison to draw upon in framing his aesthetic.

Descartes' imagination is not always one thing. Basically, he conceived of something like a hierarchy of sense, imagination, and

[36] Locke's stand in giving the fancy an inferior position to reason should be distinguished from both Descartes' and Addison's thought on the matter. Locke is thinking of the two faculties as unequal on the same level, as if occurring in two unrelated realms or compartments of the mind. Descartes, on the other hand, regards them as unequal in an ascending order, closely related in that, so far as sensible ideas are concerned, the fancy (imagination) supplies the reason (or intellect) with materials, and on occasion may receive impulse and ideas from it. In Addison's view the notion of inequality largely disappears. He does, indeed, like Descartes, think of the imagination (fancy) as operating between sense and the understanding, and his qualification that the imagination (fancy) is less gross than sense, less refined than the understanding, suggests an ascending scale. He also ventures the assertion that the pleasures of the understanding are preferable to those of the imagination, since they come from acquiring some new knowledge; but he immediately qualifies this statement by confessing that the pleasures of the imagination are as great and transporting as the other. And, altogether, he assigns to the fancy-imagination a dignity and an integrity which entitle it to our full attention and respect. Indeed, he clearly shows, in full opposition to Locke, that even historical and philosophical works gain in value when imbued with the light and grace of the imaginative touch. It is this tendency of Addison's to dignify the imagination that marks as much as anything his advance over his predecessors. No one can read the criticism of Milton, of Shakespeare, and of the old ballads and the essay on the Pleasures of the Imagination and doubt that to Addison works of the imagination have rights and values of their own at least equal to those of the reason. Addison maintained for imaginative creation and response the undeniable importance and respectability of divine law operating through human minds. He rendered unique service in helping to lay the specter of fear and distrust of the imaginative faculties which since the days of Plato had periodically haunted men's minds.

understanding, with the imagination occupying an intermediate position between sense and understanding.[37] He at one point says that sense, imagination, memory, and understanding are simply different names for one unifying agency — the cognitive faculty. Ordinarily, however, he talks of them as separate faculties.

One of the most direct definitions of imagination in Descartes occurs in the *Meditations:*

> . . . Further, the faculty of imagination which I possess, and of which, experience tells me, I make use when I apply myself to material things, is capable of persuading me of their existence; for when I consider attentively what imagination is, I find that it is nothing but a certain application of the faculty of knowledge to the body which is immediately present to it . . . .[38]

The phrase "application to the body" is of importance, for Descartes makes a good deal of the "corporeal" affinities of the imagination, meaning evidently both its nearness to the external world, as compared with the understanding, and its power to present to the mind concrete sensuous imagery. Descartes illustrates:

> . . . When I imagine a triangle, I do not conceive it only as a figure comprehended by three lines, but I also apprehend these three lines as present by the power and inward vision of my mind, and this is what I call imagining.[39]

The idea of corporeal quality of the imagination receives modification in an explanation of the modes in which pure intellect and imagination work. In its intellectual activity, says Descartes, the mind "in some manner turns on itself and considers some of the ideas which it

[37] It must not be supposed, of course, that this conception originated with Descartes. It is at least as old as Aristotle, who in the *De Anima* regards phantasy (*φαντασία*), particularly in the realm of the higher soul, as operating between sensation and conception, deriving its primary materials from sense, and in turn presenting its pictures (phantasms) to the understanding. Thus, "to the thinking soul phantasms serve as present sensations" (Hicks' translation, Cambridge, 1907, p. 141), so that under their influence "you calculate as though you had the objects before your eyes" (*ibid.*, p. 143). After Aristotle the idea of the imagination as a middle term (often one of two or more) between sense and intellect recurs frequently, usually in modified form, as in the eclectic psychology of the Christian Neoplatonists St. Augustine and Boethius, and in the elaborate faculty psychology of the Middle Ages, represented by Avicenna, Averroës, and Albertus Magnus. Hobbes, himself, so far as he identifies the imagination with memory, is really in the tradition. Descartes, however, most clearly developed the theory for the modern world, and it is to him that we can logically look for the most immediate influence on Addison.

[38] *The Philosophical Works of Descartes*, translated by Elizabeth S. Haldane and G. R. T. Ross (Cambridge, At the University Press, 1911), I: 185. This work is hereafter referred to as "Haldane and Ross." [39] *Ibid.*

possesses in itself; while in imagining it turns towards the body, and there beholds in it something conformable to the idea which it has either conceived of itself or perceived by the senses." [40] But the modification here is merely to the effect that the imagination may upon occasion conceive its own ideas, as well as receive them through the senses. Descartes, of course, had a theory of innate and other mind-born ideas, along with his sensationalism. Elsewhere, we find that the understanding, too, may supply the imagination with materials.[41]

The senses, however, at either first or second hand, furnish the imagination with most of its ideas. In addition to formal mathematical objects, such things are imagined as colors, sounds, scents, and pain. "And inasmuch as I perceive these things much better through the senses by the medium of which, and by the memory, they seemed to have reached my imagination," Descartes explains, "I believe that, in order to examine them more conveniently, it is right that I should at the same time investigate the nature of sense perception . . ." (*Meditations*, VI). Here memory aids sense in supplying the imagination with materials. It is illustrative of the difficulty we face in attempting exact definitions of terms in a man like Descartes, that in the *Rules for Direction* we find him declaring of the imagination (or fancy), "Here we give this faculty the name of memory." [42]

Descartes' accounts of sense perception and the imagination vary, but it is unnecessary to trace distinctions here. The relevant facts are that imagination and sense and understanding are distinct. Stimuli enter the mind by way of the external senses — the organs of the eye, ear, nose, and so forth. The impressions created on the structures of these organs are transmitted intact to the "common sense" (*communis sensus*), a nervous organization fitted to convey images and ideas to the imagination and the understanding. The "common sense" has in turn a "function like that of a seal and impresses on the fancy or imagination, as though on wax, those very figures and ideas which come uncontaminated and without bodily admixture from the external senses." [43] As to the functions of the imagination, it can

[40] *The Philosophical Works of Descartes*, translated by Elizabeth S. Haldane and G. R. T. Ross (Cambridge, At the University Press, 1911), I: 186.

[41] *The Principles of Philosophy*, CXC, in Haldane and Ross, I: 290–291.

[42] Haldane and Ross, I: 37.

[43] *Rules for Direction*, in Haldane and Ross, I: 37–38.

store and re-create images, as memory; it can excite the nerves and bodily organs to activity; it can furnish the understanding with ideas and images; it can bring to birth new structures. In three of these respects it is distinct from sense and understanding and, perhaps we may safely adduce, is not so gross in its operations as sense, yet not so refined as understanding.

In Descartes' conception of the power of the imagination to excite nervous activity we find his nearest approach to Addison's theory of the imagination as an agency of perceptive response. For here Descartes assigns to the Imagination the power to arouse the passions; the passions in turn are directly associated with the sensations of pleasure and pain.

Sensations of pleasure and pain are of two sorts: first, those which derive from external excitation of the senses; second, those which result from a recognition by the intellect of some fruition of good or evil. All sensory stimulation produces motion, which is transmitted from the external senses to the "common sense" — evidently the nerves are moved more vehemently than usual, yet in such a way as not to injure the body — and there is produced "a sense of gratification, which is naturally agreeable to the mind, inasmuch as it gives evidence of the powers of the body to which it is joined." If, however, the stimulus is such that the body is in some way hurt, the contrary sense of pain occurs.

Descartes conceives of the passions as likewise physical. Here, it is true, the understanding usually intervenes, but the imagination becomes an agency for the excitation of the sensation of pleasure or of pain. The six "primitive passions" are wonder, love, hatred, desire, joy, and sadness; all the others are species of these, and need not be considered separately from them.[44] These passions are, Descartes holds, emotions which, though they are of the soul,[45] are caused by the spirits and depend on the body, and should be clearly distinguished from *actions* of the mind, such as judgments which "induce the soul by its own free will to unite itself with the things which it esteems to be good, and to separate itself from those it holds to be evil, and from the emotions which these judgments excite of themselves in the soul." [46]

[44] *The Passions of the Soul*, LXIX, in Haldane and Ross, I: 363.
[45] *Ibid.*, XXVII, in Haldane and Ross, I: 344.
[46] *Ibid.*, LXXIX, in Haldane and Ross, I: 366.

The close relation which Descartes conceives to exist between purely physiological responses and the passions is shown in a remarkable exposition in his *Principles of Philosophy*, CXC. Here, too, he clearly relates the term "internal sense" to the passions and designates the imagination as the mainspring of this sense and of the passions, hence of the emotions of pleasure and pain.

Descartes, in this passage, gives man five "external" and two "internal" senses. One of the internal senses consists of the nervous system, which extends to the digestive tract "and other interior parts that serve our natural wants." Similarly, "The minute nerves, which extend to the heart and the neighborhood of the heart, operate in the other internal sense which embraces all the emotions of the mind or passions . . . ." He thus describes the process:

> . . . When the blood is pure and well-tempered, so that it dilates in the heart more readily and strongly than usual, this so enlarges and moves the little nerves scattered around the orifices, that there is thence a corresponding movement in the brain which affects the mind with a certain natural sense of cheerfulness; . . . thus the imagination of the fruition of some good does not contain in itself the sensation of joy, but it causes the animal spirits to pass from the brain to the muscles in which these nerves are inserted; and thus dilating the orifices of the heart, it causes these small nerves to move in the manner which necessarily produces the sensation of joy.

Thus good news is first adjudged good by the mind with intellectual joy. When this intellectual joy proceeds (from the understanding) to the imagination, "the spirits flow from the brain to the muscles about the heart and these excite a movement in the small nerves by which another motion is excited in the brain which gives the soul the sensation of animal joy." [47]

It should be noted that the pleasurable emotion here described as arising through intervention of the imagination is distinguished by Descartes from "intellectual joy." In further exposition he makes this distinction even more clear:

> When we are given news the mind first judges of it, and if it is good it rejoices with that intellectual joy which is independent of any emotion of the body . . . ." [48]

Defining "joy," in *The Passions of the Soul*, he describes intellectual joy as an "agreeable emotion of the soul," at the perception of good, but at once admits that this intellectual pleasure is almost invariably

[47] *The Principles of Philosophy*, CXC, in Haldane and Ross, I: 290–291.
[48] *Ibid.*, p. 291.

accompanied by a physiological response initiated by the imagination:

> . . . for as soon as our understanding perceives that we possess some good thing, even although this good may be so different from all that pertains to body that it is not in the least capable of being imagined, imagination does not fail immediately to make some impression in the brain from which proceeds the movement of the spirits which excites the passion of joy.[49]

In both of the passages I have cited, the intellect or soul is intermediary between the original cause of joy and the physiological passion induced by imaginative excitation. This, of course, does not parallel Addison's view; for with Addison imaginative response, at least so far as objects of the primary imagination are involved, is direct, without intervention of the intellect: "It is but opening the Eye and the Scene enters"; we "immediately assent to the Beauty of an Object, without enquiring into the particular Causes and Occasions of it."

Descartes goes on to point out, however, that there are cases in which pleasure is excited without any apparent recognition of good or evil by the intellect. It often happens, he explains, that we feel sad or joyful without observing the good or the evil which is the cause — "when this good or evil form their impressions in the brain without the intermission of the soul." [50] Gaiety, he says, may proceed "from no function of the Understanding, but only from the impressions which the movement of the spirits causes in the brain." [51] In such cases "the titillation of the senses is so nearly followed by joy, and pain by sadness, that the greater part of mankind does not distinguish the two." The cause of this phenomenon is that "all that we call pleasurable sensation or agreeable sentiment is simply due to the fact that the objects of sense excite some movement in the nerves which would be capable of harming them had they not strength sufficient to resist the movement." Descartes tentatively extends this

[49] XCI, in Haldane and Ross, I: 372. It was this quite constant tendency to relate the passions and the imagination to physical activities which Descartes shows, in common with Hobbes and Locke, that caused Shaftesbury to speak disdainfully of the philosophers of the new school as "these Physiologists"; Addison, on the contrary, heard such doctrine gladly. It helped him to a solution of his main problem in the essay on the imagination: that is, What is it that excites our pleasure in beautiful objects in nature, and what is it that gives a pleasure to beautiful passages in literature?

[50] *The Passions of the Soul*, XCIII, in Haldane and Ross, I: 373.

[51] *Ibid.*, XCIV, in Haldane and Ross, I: 373.

physiological explanation to include the pleasure to be had from art. "It is almost the same reason," he says, "which brings it about that we naturally take pleasure in being moved by all sorts of passions — when these passions are only caused by the strange adventures which we see represented in a theatre, or by other similar means which . . . seem pleasurably to excite our soul in affecting it." [52]

Thus not only could Addison have had from Descartes authority for speaking of agreeable impressions received from objects of sense as pleasures of the imagination, but he could likewise have had from him suggestions for designating the impressions received from literature as imaginative rather than intellectual. This appears even more clearly in a passage in the *Principles of Philosophy*. Words, whether spoken or written, says Descartes, explaining the power of motions from objects to arouse feeling or sensations independent of direct imagery from the body causing the motions, excite in us all sorts of thoughts and emotions. On the same paper, simply by moving the pen this way or that, a writer can bring to the minds of his readers images of battles, tempests, and furies, or sensations of quietude, peace, and pleasantness, or yet again the passions of love and joy.

> Someone will perhaps reply that writing and speech do not immediately excite any passion in the mind, or imagination of things different from the letters and sounds, but simply, so to speak, various acts of the understanding; and from these the mind, making them the occasion, then forms for itself the imaginations of a variety of things. But what shall we say of the sensations of what is painful and pleasurable? If a sword moved towards our body cuts it, from this alone pain results which is certainly not less different from the local movement of the sword or of the part of the body which is cut, than are colour or sound or smell or taste. And therefore, as we see clearly that the sensation of pain is easily excited in us from the fact alone that certain parts of our body are locally disturbed by the contact with certain other bodies, we may conclude that our mind is of such a nature that certain local motions can excite in it all the affections belonging to all the other senses.[53]

The upshot of this argument is that the symbols of language have power so to excite our nervous organization as to produce directly, without the intervention of the understanding, imaginative response. Neither the argument nor the conclusion is too clearly formulated, to be sure, but, even so, the meaning emerges. Descartes is intimating a theory of representative art, in which objects are pre-

[52] *The Passions of the Soul*, XCIV, in Haldane and Ross, 1:373.
[53] *The Principles of Philosophy*, CXVII, in Haldane and Ross, I:294.

sented through symbols which re-create in the mind of the reader not images of the symbols but images, emotions, and associations belonging to the object represented.

It will be readily seen that Descartes is in certain phases of his theory on ground that is very near Addison indeed. It is true that in touching upon the functions of the imagination and the "internal sense" Descartes only skirts the issues involved in Addison's later theory, but his implications cannot be questioned. Aesthetic pleasure is a direct effect of nervous response to external stimuli, and the imagination is the agency through which this pleasure is excited. Such effects may therefore, without stretching the point too far, be called "Pleasures of the Imagination."

Thus we find in Locke and Descartes and, to a lesser extent, in Hobbes, the components that enter into the psychology upon which Addison built his conception of the imagination as perceptive response. All three had considered in one way or another the problem of pleasure and pain; all three had more or less pointedly related pleasure and pain to the passions; all had ascribed the capacity to experience these emotions to a sort of sixth sense, or to internal sense or sensation. Locke particularly had invited investigation, through the introspective method, of the true nature of this complex phenomenon. Descartes had furnished most clearly the conception of the imagination as an intermediary between sense and understanding, though this is also implicit in Hobbes; and it was Descartes, too, who had gone so far as to link the imagination with internal sensations of pleasure and pain, extending this function, somewhat tentatively and obscurely, to be sure, to the enjoyment of literature.

Yet, though the psychological basis is here, the completed conception is not. Addison's theory is eclectic. It cannot be facilely traced too exclusively to Hobbes, to Descartes, or to Locke. From these philosophers Addison unquestionably derived much, as I have tried to show. There remains, still, to account for the basic idea of imagination as the organ of taste. The Spaniard Gracián and the Frenchman St. Évremond, among others, no doubt contributed at this point, and possibly Shaftesbury. Then there are the ideas of novelty and of the sublime which enter prominently into Addison's theory. Hobbes and Locke and, in a small way, Descartes could have furnished suggestions for novelty; but it is quite as prob-

able that Gracián, Le Bossu, Rapin, Dryden, and Dennis, even Longinus, were sources here.[54] As for the notion of sublimity, Longinus is the most likely single influence, but it is Longinus superimposed upon the new psychology, with variations from sundry intervening writers, including Dennis and Boileau, and with additions of Addison's own. All these items must be taken into consideration in accounting for Addison's theory as it stands, at best but imperfectly sketched, tentative and suggestive rather than outright and complete.

Addison's contribution is not so much in the discovery of new elements of aesthetic thought as in the combination he makes of the old. It lies as much in method as in theory. A Lockian and an empiricist, the method he adopts is patently the introspective method of the new philosophy. He proposes to look into the mind to find there what objects please, how they please, and why. He will analyze both the causes and the effects of the pleasures in question, and from this analysis will attempt to deduce new principles by which to judge art, in place of the then prevailing Rules of neoclassic criticism. There is involved in this procedure, certainly, no new principle of psychology. It is merely an adaptation of a tried method to a limited specific end: the discovery of the sources and the nature of what we now call aesthetic pleasure. What was new here, and even this was not entirely new, except as it was more extensive and more deliberate than any previous attempt of the kind, was the conscious purpose to apply this scientific-philosophic method to the problems of literary merit and appeal. As such it is significant; had Addison done nothing more, he would have deserved a place among important aestheticians.

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[54] I am presenting a more detailed account of these elements in Addison's theory in a longer study which I hope to have completed at an early date.

LOVE IN *ANTONY AND CLEOPATRA*

JOHN WILCOX

THE decade from *Romeo and Juliet* to *Antony and Cleopatra* was the time when Shakespeare passed from the youthful age of thirty into the maturity of his forties. In this interval his treatment of love also passed from enthusiasms that recall adolescence into emotions associated with full maturity. These two tragedies may well be contrasted for evidence of growth in the poet's conception of love between men and women. The ideas about the subject that I find in the later play are the results of such a study.

When we approach the problem as Shakespeare did, through the pages of North's *Plutarch*, and read "The Life of Marcus Antonius" with attention on the love story, we observe a wide breach in the logic of each of the two principal characters. The career of Mark Antony before he knew Cleopatra makes his afterconduct about the last thing anyone would predict, for if ever one had training in the maintenance of an amatory life as a side issue to a career, it was this very man. From his adolescent days he had surrendered himself to dissipation and "vain expenses upon women," and he "was given to love" throughout the succeeding years, conducting himself after the manner of profligates of all time.[1] But he developed military prowess, political skill, and oratorical powers at the same time. If practice in taking love lightly were ever to develop ability, we should find it exemplified in this triple pillar of the world, who is, instead, proverbial as the man who lost all for love.

Plutarch's explanation of Cleopatra's motives in winning and holding Antony does not prepare us to understand what he tells us about her conduct during and after Antony's decline and fall. Plutarch believed that she deliberately entrapped Antony by the artful display of the beauty and charm that had won Caesar and Gnaeius Pompey.[2] He says later that, even after Antony broke

[1] Brooke, C. F. Tucker, *Shakespeare's Plutarch* (Chatto & Windus, London, 1909), II: 1–15.

[2] *Ibid.*, p. 37.

away from her bad influence, to marry Octavia, "the unreined lust of concupiscence . . . put out of Antonius' head all honest . . . thoughts." [3] As a consequence, the Roman returned to his Oriental slavery and remained so "enchanted with the sweet poison of her love" that he failed in his Asian campaigns and brought angry Romans buzzing about him and his Egyptian queen.[4] But the regal charmer, who knew unerringly how to sell her voluptuous body in the highest market, in the end did not waver, according to Plutarch, in her loyalty to the man whose career she had ruined.[5] After the military debacle she took a vow to die with Antony,[6] and she kept that vow in spite of the blandishments of Octavius Caesar and his emissaries.

In accounting for these events Plutarch says repeatedly that Antony acted as he did because of a moral weakness,[7] and that Cleopatra killed herself, not from fear of gracing a Roman triumph but from loyalty to her paramour.[8] Shakespeare did not accept these conclusions. Ignoring Plutarch, he reopened two questions: Why did Antony vacillate between Cleopatra and Rome? Why did Cleopatra lead Antony to ruin though she was loyal enough to go down in his disaster? The playwright was compelled to fall back upon his own observation and experience, for out of these must grow that imaginative insight into the consciousness of created characters from which all great fiction is ultimately derived. Where Shakespeare got his knowledge of life I do not presume to say. I am content to point out what seem to be his answers to these questions.

As soon as the play begins, we see that Shakespeare has deftly passed over years of Plutarch's narrative and placed his opening moment at the significant episode of the turning of Antony's eyes from Egypt to Rome.[9] This indicates a clear intention to press the historical story into the background and bring forward the love story, the relation between the two characters for whom his play is

[3] Brooke, C. F. Tucker, *Shakespeare's Plutarch* (Chatto & Windus, London, 1909), II: 55–56.

[4] *Ibid.*, pp. 55–87. [5] *Ibid.*, pp. 128–133. [6] *Ibid.*, p. 114.

[7] Even when giving Antony's explanation of his conduct, that the nobility of great Romans ought to be perpetuated by the planting of "seed in divers places" (*ibid.*, pp. 56–57), Plutarch says he "could finely cloak his shameful deeds with fine words." [8] *Ibid.*, pp. 131–132.

[9] Just one third of North's *Plutarch* is devoted to events that precede the death of Fulvia, with which Shakespeare opens (*ibid.*, p. 46).

named.[10] The poet has boldly seized the nettle of Antony's vacillation between love and career for this initial emphasis.

Let us glance at a modern attempt to understand this emotional dilemma, and then return to our play. Freud explains character through the urge of the sexual libido to arrive at complete expression. Adler undertakes to replace the sexual urge with a masculine will to power, currently known as ego in the psychoanalytic jargon. The clash between the two views has resulted in another explanation, associated perhaps most notably with the Zurich school of psychoanalysis.[11] The basic fact of the male human's character, this school explains, is that he is the battleground of both motives. As the possessor of a libido, he yearns to lose himself in his love, to give up everything in life to this urge. For the sexual life, pleasure-giving though it is, belongs in the category of ego-destroying forces. The ego therefore leads a counterfight against love and in favor of the urge to self-assertion and personal worth.

> The fear, shame, and loathing which, according to Freud, form the resistances interfering with the sexual impulse in man and which have prevented him from manifesting his sexuality simply and naturally according to his desires as animals do, all belong to the great category of the ego instincts. . . .
>
> Thus the principle of individual preservation in its more complex form could express itself through the revolt of the ego, in shame, loathing and fear, and the sexual restriction which has characterized the last two thousand years may have perhaps a direct relation to the enormous cultural progress in thought, in art, in science and mechanics which has characterized this age.[12]

Man's life is a conflict between two urges, neither of which can be finally silenced except by old age or death. When his love is attained, his thoughts turn away from his bliss to his neglected affairs. When his career causes him to abandon love, he is equally disturbed. Moments come when a man will sacrifice either for the other, but he

[10] This judgment is at variance with the usual acceptance of *Antony and Cleopatra* as a history play of the type of *Julius Caesar*. For an attractive recent discussion from this point of view see Harley Granville-Barker, *Prefaces to Shakespeare*, Second Series (London, 1930), pp. 111–233. Mr. Granville-Barker also follows the conventional interpretation in holding that the morality of Antony and of Cleopatra is the key to their characters. I hold that a realistic presentation of their experience with love was Shakespeare's real end.

[11] See, for example, Beatrice Hinkle, *The Re-creating of the Individual; A Study of Psychological Types and Their Relation to Psychoanalysis* (Harcourt, Brace and Company, New York, 1923), pp. 19–49.

[12] *Ibid.*, pp. 37–38. Freudians, of course, use the word "sexuality" so as to include those experiences which common usage terms "love."

will rue the decision thereafter. The struggle within a man's soul between love and career, say these moderns, is natural and inevitable. The greater the man's intensity as a lover, the greater his capacities as a man of action, the more bitter the conflict between the warring forces, forces which have driven despairing man into every sort of solution from the harem to the cell of the anchorite.[13]

This modern explanation, the ultimate validity of which I have no intention of affirming or denying, does not seem to have been wholly absent from the experience of the Shakespeare who wrote the sonnets. Note the implications in Sonnet CXXIX:

> The expense of spirit in a waste of shame
> Is lust in action; and till action, lust
> Is perjur'd, murderous, bloody, full of blame,
> Savage, extreme, rude, cruel, not to trust;
> Enjoy'd no sooner but despised straight;
> Past reason hunted; and no sooner had,
> Past reason hated, as a swallow'd bait,
> On purpose laid to make the taker mad:
> Mad in pursuit, and in possession so;
> Had, having, and in quest to have, extreme;
> A bliss in proof, — and prov'd, a very woe;
> Before, a joy proposed; behind, a dream.
> All this the world well knows; yet none knows well
> To shun the heaven that leads men to this hell.

Let us now return to the opening scene of *Antony and Cleopatra*. Roman messengers appear to disturb the bliss of the two great lovers. When Cleopatra's intuition warns her of the danger, Antony exclaims, a bit too rhetorically perhaps:

> Let Rome in Tiber melt, and the wide arch
> Of the rang'd empire fall! Here is my space.
> Kingdoms are clay; our dungy earth alike
> Feeds beasts as man; the nobleness of life
> Is to do thus; when such a mutual pair
> And such a twain can do't, in which I bind,
> On pain of punishment, the world to weet
> We stand up peerless.[14]

Shakespeare amplifies Plutarch's hint and alters the latter's statement of facts in order to give Antony a more sharply defined reversal

[13] See Beatrice Hinkle, *The Re-creating of the Individual; A Study of Psychological Types and Their Relation to Psychoanalysis* (Harcourt, Brace and Company, New York, 1923), pp. 39–40, 46.

[14] I, i, 33–40. These and succeeding citations of text refer to the Oxford Shakespeare.

of mood for the next scene.[15] Within a day of his willingness to "let Rome in Tiber melt" Antony is receiving the messengers he had repulsed. He energetically assumes the task of rebuilding his political fences and plans a hasty return to Italy. He is even capable of deciding, in repudiation of his declaration of the day before,

I must from this enchanting queen break off.[16]

In reply to the protests of Enobarbus that "her passions are made of nothing but the finest parts of pure love," Antony can say heartlessly:

Would I had never seen her! [17]

Has not Shakespeare offered this reversal of moods as the key to Antony's part in the play? If so, we may infer that Shakespeare's experience, like the observations of the modern psychologists, affirmed the existence of opposing urges, the one toward love and the other toward a manly career.

Swinging to one extreme, Antony takes a scant farewell and leaves Egypt in order to renew his coalition with the Roman politicians. As a sort of bridge-burning conclusion to the bargain with the other members of the triumvirate,[18] he makes an alliance with Octavia, not a love match but yet some sort of substitute for the love he has abandoned. During several succeeding years, contracted into part of an act in Shakespeare's version, his strength of character keeps him from his serpent of the Nile, but eventually his career seems dust in his mouth, and he returns to Cleopatra by successive stages, as he himself anticipated he would do.[19] First he takes Octavia toward the East;[20] then he sends her home alone;[21] suddenly Cleopatra beckons,[22] and he is back in Egypt.[23]

Although Antony has not abandoned his political life, he tries henceforth to maintain his place in his struggle with Octavius without going outside the range of Cleopatra's influence. He allows her

[15] According to Plutarch (Brooke, *op. cit.*, pp. 45–46), when news came to Egypt that Fulvia was making trouble with Caesar and that Labienus was conquering Asia, Antony set out against the Parthians. When he got as far as Phoenicia, more letters turned him toward Italy, where he arrived before Fulvia's death. There is no hint of the tense third scene of Shakespeare's play.

[16] I, ii, 131. [17] I, ii, 155.

[18] Plutarch and Shakespeare are in essential agreement.

[19] II, iii, 38–40. [20] III, ii. [21] III, iv.

[22] III, iii, 46–47. [23] III, vi.

to sway his judgment against battle on land. In the height of the sea fight at Actium he turns shamefully to follow her fleeing ship and thus destroys his chances for victory.[24] For the moment he surrenders all hope of success.

> . . . Friends, come hither:
> I am so lated in the world that I
> Have lost my way for ever. I have a ship
> Laden with gold; take that, divide it; fly,
> And make your peace with Caesar.[25]

But this does not mean that he has surrendered his career to the satisfaction of his love. He still struggles, and his meeting with Cleopatra is filled with dramatic tension between his ego and his libido, although he now can acknowledge,

> . . . o'er my spirit
> Thy full supremacy thou knew'st.[26]

Until his very death his life is an alternation between reviling hatred of her as the cause of his downfall and ecstatic suffusion with a sense of her great love for him.[27] He cannot believe she is good when the failure of his career is evident; at his last defeat, for example, he tells Eros:

> . . . and the queen,
> Whose heart I thought I had, for she had mine,
> . . . . . .
> . . . she, Eros, has
> Pack'd cards with Caesar, and false-play'd my glory
> Unto an enemy's triumph.[28]

But just then comes the false news of Cleopatra's suicide, her trump card of feminine wile by which she hopes to win him back; instantly Antony is all lover, all remorse for his abuse, all for joining her in death.

> I will o'ertake thee, Cleopatra, and
> Weep for my pardon.[29]

Such emotional dissonances have appeared at intervals throughout the play, until now Antony's suicide resolves them all in the tenderly harmonious farewell within Cleopatra's monument, in which he

[24] III, viii. [25] III, ix, 2–6. [26] III, ix, 58–59.
[27] Cf. III, ix, 51–54, with III, ix, 69–74. Cf. III, xi, 85–152, with III, xi, 167–200.
[28] IV, xii, 15–20. [29] IV, xii, 44–45.

avoids reproaching her for his death, and she loyally spurns his suggestions of safety for herself:

> My resolution and my hands I'll trust;
> None about Caesar.[30]

This intention she reaffirms to her women just after his death:

> . . . what's brave, what's noble,
> Let's do it after the high Roman fashion,
> And make death proud to take us.[31]

Thus Antony's vacillation is shown as the natural outcome of his being both a man of action and a lover. His tragic end is the consequence of the strife in this dual rôle, not the result of a tragic fault in his character; it comes because man wears the yoke of inauspicious stars.

Cleopatra's part of the story, on the other hand, is differently motivated. She leads her lover to ruin because she is impelled to satisfy herself of the reality of her union with him. She tugs mightily at the strings that hold him, just to assure herself that they are strong. Finally satisfied, she discovers that she has blindly led him to destruction. She has no wish to do other than accept ruin with him. As she dies her reverie is on him, and her everlasting union with him:

> . . . husband, I come:
> Now to that name my courage prove my title! [32]

Let us review her part in the play and note that Shakespeare's emphasis makes this interpretation evident. At Cleopatra's entrance in the opening scene the significant first words that Shakespeare puts on her lips express the querulous lover's hunger for perfection in love:

> If it be love indeed, tell me how much.[33]

This same question continues to plague Cleopatra until, at the climax in the third act, Antony

> Claps on his sea-wing, and like a doting mallard,
> Leaving the fight in height, flies after her.[34]

Shakespeare seems to have conceived Cleopatra as a genuine lover and felt that her capricious conduct could be given a living consistency

[30] IV, xiii, 49–50. [31] IV, xiii, 86–88. [32] V, ii, 285–286.
[33] I, i, 14. [34] III, viii, 29–30.

if it was offered as an expression of the desire for a perfect union, of that yearning for certainty in an uncertain world which has haunted lovers always. By the use of insight where Plutarch was obtuse, he makes her apparent fickleness the consequence of a poignantly intense love, a love struggling for supremacy over Antony's political ambition. She wishes to possess her man of men, to possess him completely, and she fights instinctively against all the forces that draw him from her. In politics or statecraft she has no interest.

To Antony's rhetorical willingness to "let Rome in Tiber melt" she is skeptical, and she baits him with taunts about Fulvia, because she needs the reassurance of even his thin denials. Her love compels her to array every charm to the utmost as soon as "a Roman thought hath struck him." A day later, when she is wavering between the various moods she might assume in Antony's presence, she is willing to discuss the technique of feminine wile with Charmian, but her decision to select the adverse mood, to force herself into Antony's thoughts, is the act of a loving, suffering woman, not the plotting of a mercenary female. Shakespeare so holds, for he provides several alternations of scene between Egypt and Rome so that he may portray the deserted Cleopatra faithful to Antony's memory, living on her own recollections of loving days and single-mindedly determined to call him to her when and how she can. When she finally brings him back to Egypt at the as yet unpaid price of empire, she is still in a state of uncertainty over him; she applies

> . . . that fatal knife,
> Deep questioning, which probes to endless dole.[35]

The ruin she brings about his head and hers is the "dusty answer" to

> . . . the soul
> When hot for certainties in this our life!

As presented by Shakespeare, Cleopatra's technique of fascination is simpler than it is in Plutarch's account. The playwright elected to present her as a woman who dominated by an amorous gaiety when all is well and, when crossed, by the exhibition of a contrary mood to which she forces her lover:[36]

[35] The last "sonnet" in George Meredith's *Modern Love.*

[36] See Brooke, *op. cit.*, pp. 40–41, 43–45; the hint on page 84 is used most extensively.

> . . . if you find him sad,
> Say I am dancing; if in mirth, report
> That I am sudden sick.[37]

This motivates her act of bullying Antony into fighting at sea, when he is best equipped for land warfare. It is significant that Shakespeare does not assign to her, as Plutarch does, the motive of deliberate, planned treachery for either part of this trick, the sea fight or the sea flight. Not treachery but the simple desire to lead her lover where he would not choose to go causes her to flee from the battle. Her explanation to him,

> . . . I little thought
> You would have follow'd,[38]

is a deft covering of the mingled hope and fear that impelled her to put him to the test. Thereafter Cleopatra accepts Antony unquestioningly and even includes his career as part of him, not as her rival for him. She joins heartily in his efforts to regain his lost grip on the political world, but it is too late.

By giving no reason for her courtesy to Thyreus Shakespeare leaves the way open for us to believe that she is planning some sort of sacrifice of herself to redeem Antony with Caesar. Plutarch surrounds Cleopatra with flattering and false-hearted advisers who help her decide momentous issues; Shakespeare assigns her loyal servants and companions. He gives his heroine the strength to stand alone; no one makes up her mind for her. It is thus consistent to ascribe such an unexpressed motive to her in a scene where it is dramatically impossible to express it. At any rate, Plutarch made little of the incident of Antony's finding her in consultation with Thyreus.[39] Shakespeare expanded it into the major scene of Antony's rage against Cleopatra. The purpose, perhaps, is revealed in his emphasis on her meekness, which is not in Plutarch, except possibly by inference. After all it is little short of amazing that this imperious queen, used to haling the bearers of bad news by the hair, should stand by quietly while Antony plies her with every vile name he can think of.

> You were half blasted ere I knew you: ha!
> . . . . .

[37] I, iii, 3–5.
[38] III, ix, 55–56.
[39] Cf. Brooke, *op. cit.*, pp. 116–117, and *Antony and Cleopatra*, III, xi, 47–167.

You have been a boggler ever:
. . . . . .
I found you as a morsel, cold upon
Dead Caesar's trencher;

To all these revilings she mildly asks at his successive pauses for breath:

O! is't come to this?
. . . . . .
Wherefore is this?
. . . . . .
Have you done yet?
. . . . . .
Not know me yet?

The scene slides into another reconciliation. They decide to celebrate her birthday in "one other gaudy night." Does not this imply that Antony's anger is music to her fearful ears, unmistakable proof that his love for her dominates his life? Instead of resenting his abuse, she aids Antony, almost mothers him. The morning scene before the last battle, when the regal lady with her own hands buckles on his armor, is a touch of domestic felicity, of perfect mutual acceptance. Before this last unhappy day is over his appalling rage and unjustified doubt send her to her monument to make her ill-starred attempt to woo him back once more with a false message. Her technique achieves catastrophic success: it brings her lover on his death litter, dying that he might join her. Surprising as the results are, her intentions are unquestionably loyal: she wishes to dissolve all differences as she has managed to dissolve them hitherto.

So far I have been dealing with the emotional experience of the lovers, whereas a love story has two aspects, the way it feels to the principals and the way it looks to the untouched outsiders. The latter view has the support of morality generally, but we must not forget that the customary contempt for the weakness of the man who sacrifices his life and career to his love is after all the rationalization of a fear, a rationalization which employs the familiar technique of trying to despise what one is afraid of.

. . . the shame and loathing postulated by Freud as the great resistance to sexuality, but also the moral reaction and struggle against it which has culminated in the puritan excess of our epoch, were born out of an inherent need of man to protect and discipline himself against the danger of succumbing to the domination of his sexual desires.[40]

[40] Hinkle, *op. cit.*, p. 38.

To give the moral test, then, as a substitute for the inner experience of the conflict between duty and desire is to beg the question completely. We must therefore not hastily assume that the outside view is the poet's own attitude, just because it happens to conform to our personal code or to conventional standards. If we accept the evidence of the play and observe the emphasis which the poet designs, we see that he gives both sides, maintaining a personal and moral aloofness. Although he tells what the world says and thinks, he does not forget to deal sympathetically with his chief figures, to offer their experiences as they feel them. We should not be surprised if their acts, emotions, and relations seem less repulsive to them than to the observers, but we must not forget that both sides are really biased.

To give both attitudes, Shakespeare opens his play with the observer's story. He places an otherwise unemployed Philo on the side lines of the initial scene and lets him express in one impressive indictment all that could be said.

> Nay, but this dotage of our general's
> O'erflows the measure; those his goodly eyes,
> That o'er the files and musters of the war
> Have glow'd like plated Mars, now bend, now turn
> The office and devotion of their view
> Upon a tawny front; his captain's heart,
> Which in the scuffles of great fights hath burst
> The buckles on his breast, reneges all temper,
> And is become the bellows and the fan
> To cool a gipsy's lust. Look! where they come.
>
> (*Flourish. Enter Antony and Cleopatra, with their trains; Eunuchs fanning her.*)
>
> Take but good note, and you shall see in him
> The triple pillar of the world transform'd
> Into a strumpet's fool; behold and see.[41]

Thus the poet points out to us that in Antony love and career are in conflict. Philo's almost anonymous voice expresses sympathy for one side, leaving to the lovers the interpretation of the other. To the practical-minded outsider love is very likely dotage and lust; to him a woman who has had successive *amours* may seem to be a strumpet, and a great passion must surely be a folly. But his judgments are partisan. To show the conflicting views Shakespeare went to considerable pains to create Enobarbus, who is not

[41] I, i, 1–13.

found in Plutarch. The reason is surely made clear in his employment of him as one whose relations to the principals give him an opportunity to understand both sides, to occupy a middle ground of opinion about the lovers. He can see their folly, but he can also see the fascination that their union holds for them. It is he who flippantly observes that she is a "wonderful piece of work which not to have been blessed withal would have discredited your travel." [42] He describes the first meeting upon the river Cydnus in much-quoted lines.[43] He foresees that Antony can never really leave Cleopatra, for

> Age cannot wither her, nor custom stale
> Her infinite variety; [44]

Enobarbus understands that Antony "will to his Egyptian dish again; . . . Antony will use his affection where it is; he married but his occasion here." [45] Later he urges Cleopatra to keep away from the battle.[46] He protests to Antony against the folly of fighting by sea.[47] As his forebodings are realized, discretion calls for his desertion. But after he goes over to the camp of Caesar, he dies of sheer will not to live (aided perhaps by malaria), because he has not remained loyal.[48] What reason can we find for Shakespeare's inclusion of this episode except to point out that Antony and Cleopatra were people who would actuate such loyalty and earn such devotion also as Iras and Charmian pay? Here is a faithfulness that transcends self-interest and testifies to the greatness of those who inspire it. Thus the outsiders bring in their view to contrast with all that the lovers can show for themselves. The poet has thereby given the story a realistic treatment that includes the dramatic excellence of effective contrast. All in all, I find it possible to understand what I read in the play only when I think of it as a sympathetic retelling of a great love between two intense, sincere lovers.[49] They had their joys, their sorrows; their doubts, their

[42] I, ii, 157–158. [43] II, ii, 195–237. [44] II, ii, 240–241.
[45] II, vi, 130–135. [46] III, vii, 1–20. [47] III, vii, 34–48.
[48] III, xi, 194–200; IV, v, vi, ix.

[49] The results of my study are in opposition to the accepted doctrine that Shakespeare's treatment was primarily moral. If my thesis holds, it may later be useful to work out its implications in relation to the existing body of criticism and interpretation, but the refutation of everyone from Coleridge to MacCallum is beyond the scope of this study.

After my own position was developed, I found anticipatory corroboration

reconciliations; their follies, the penalties of their follies. But most of all they were a great pair, an imperial pair, a loving pair. Even dull, insensitive Octavius could perceive that

> No grave upon the earth shall clip in it
> A pair so famous.[50]

I hazard the judgment that in this play Shakespeare was primarily interested in being true to the inner experience of love in marriage, not in moral precepts. The irregularity of the lovers' relation from a legal point of view gave him no concern. Human nature is more permanent than even the Decalogue, and to the author of the *Sonnets* much more interesting. Antony and Cleopatra are, in psychological truth, man and wife. The twist of immorality provides a fortuitous individuality to the union, not its essential nature. I do not see either why the man who loved the Dark Lady would assume that a variety of love affairs in the past should destroy the sincerity or the intensity of one in the present. This notion, too, has more foundation in moral needs than in psychological reality. Did not Shakespeare know by the age of forty-three that amatory capacity is more likely to atrophy than to grow through disuse? That great lovers are experienced lovers, not adolescent neophytes in the art? In his earlier plays he has often reflected the immature view that the only problem in love is that of attaining. Interest is centered in the simple question of whether Jack shall have his Jill. The love tragedy of *Romeo and Juliet*, for example, is based on the adolescent belief that union with the be-

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from H. H. Furness, *A New Variorum Edition of Shakespeare, The Tragedie of Anthonie and Cleopatra* (Philadelphia, 1907), pp. ix–xiv. He feels that most criticism of *Antony and Cleopatra* reflects the tone of Plutarch rather than of Shakespeare. This is particularly true of the moral attitude. Plutarch held the moral reins taut, constantly pointing out the wickedness of our principals' acts. The simple fact that Shakespeare chose to ignore nearly all of this is important. For example, even when Roman thoughts strike him, Antony cannot join the outsiders fully. He can say to Enobarbus,

> These strong Egyptian fetters I must break,
> Or lose myself in dotage. (I, ii, 119–120)

He can admit that Cleopatra is an "enchanting queen" from whom he must break off, and that she is "cunning past man's thought." He can even wish he had never seen her. But he never accuses her of inconstancy or insincerity except when in a rage.

[50] V, ii, 356–357.

loved is bliss eternal and that loss of the beloved destroys all reason for living. By the time of *Antony and Cleopatra* Shakespeare was aware of the less romantic truth that life is an eternal problem. He could then see that the union of lovers merely alters the nature of the riddle. It shifts the front on which the battle of life must be fought. In the end, love, attained or unattained, adds to the perplexity of life and gives increased weight to the blows that an unkind fate may shower on those who live not wisely but too well.

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DOES r_{ab} EQUAL $r_{ag}r_{bg}$?

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Part I

THE Spearman formula $r_{ab} = r_{ag}r_{bg}$ has become so generally accepted as a statistical tool that there is no longer any question of its validity. The probable error of r_{ab} has, however, caused much discussion and the development of a number of formulas, all too involved for extended use. The immediate purpose of this paper is to throw some light upon the agreement between empirically obtained r_{ab} values and those computed by means of the formula.

The formula was obtained by Spearman by writing the partial correlation formula as follows:

$$r_{ab \cdot g} = \frac{r_{ab} - r_{ag}r_{bg}}{\sqrt{(1 - r^2_{ag})(1 - r^2_{bg})}}$$

Since a and b are correlated only through their association with g, when the effect of g is removed the correlation must become zero. In this case $r_{ab} - r_{ag}r_{bg} = 0$, and $r_{ab} = r_{ag}r_{bg}$. This equation gives accurate, meaningful results only when the two tests measure the same quality and when the errors of measurement are random.

Having obtained three series of values, for r_{ab}, r_{ag}, and r_{bg}, respectively, how close an accord may we expect to find between the corresponding values for r_{ab}, one set having been obtained empirically, the other by the application of the equation? Theoretically, the upper limit of the empirical r_{ab} terms is 1.00, for there is no reason why cause or chance should not, from time to time, give perfect agreement. If the curve of distribution of the computed r_{ab} terms is normal, the lower limit of r_{ab} should be as far below the average as the upper limit is above. In this case the probable error would be a definite function of the range. How are the details of this picture filled in in practice?

To answer this question, materials obtained from experiments on sensory discrimination were employed. To bring the problem to its sharpest focus, each series of results to be discussed was planned to

meet the condition that $r_{ag} = r_{bg}$. The number of items in the discrimination tests was always ten. In series 1 the results obtained from twenty subjects, each series of ranks having a correlation of .939 with the criterion, were intercorrelated. The theoretical r_{ab} should then be equal to $.939^2$ or .882. The 190 computed coefficients ranged from 1.00 to .79, with a mean at .884 and a median at .884. The upper limit of the curve of distribution agrees with the theoretical demands, but the lower limit should be .768, instead of .79, as found. The theoretical probable error of a correlation coefficient of .882 is .046, whereas the probable error of the distribution of the 190 coefficients is only .035.

In series 2 the value of r_{ag} and r_{bg} was .879. The theoretical value of r_{ab} is therefore .771. The upper limit should be 1.00; the lower, if the curve is symmetrical, .542. The distribution of the 190 coefficients giving the r_{ab} values has an upper limit of 1.00, but a lower limit of .60, which is .06 higher than theory demands. The mean value of the coefficients is .778; the median, .777.

In series 3 $r_{ag} = r_{bg} = .818$, which gives an r_{ab} equal to .670. The empirical curve of distribution has a mean of .672 and a median of .668. The highest value is 1.00; the lowest, .41, as compared with the theoretical .340. The probable error of the correlation is .116; the probable error of the distribution is .077.

Series 4 was based upon r_{ag} and r_{bg} values of .757, with a corresponding r_{ab} of .580. The empirical mean was .580; the median, .570. The range extended from 1.00 to .22, whereas a symmetrical curve would have established a lower limit of .16. The probable error of a coefficient of .580, when n is 10, is .142, whereas the probable error of the distribution was .085.

In series 5 the correlation with the criterion was .697, with a corresponding r_{ab} of .484. The distribution of the 190 correlations had a mean of .466 and a median of .455. The range extended from .94 to .03, as compared with a theoretical range from 1.00 to − .032. The probable error of the correlation coefficient is .166; the probable error of the distribution, .133.

Series 6, planned to give r_{ab} equal to .405, with r_{ag} and r_{bg} equal to .636, gave a mean of .421 and a median of .409. The range, from .98 to − .11, is to be compared with a theoretical range from 1.00 to − .190. The probable error of the coefficient of .405 is .177, whereas the probable error of the distribution is .166.

Series 7 gives the results obtained from r_{ag} and r_{bg} equal to .576, with a corresponding r_{ab} of .332. The mean of the distribution was .324; the median, .329. The range was from .89 to − .26, as contrasted with a theoretical range from 1.00 to − .336. The probable error of the coefficient is .190; the probable error of the distribution, .128.

Series 8, based on a correlation with the criterion of .515 and an r_{ab} of .265, gave a mean of .261 and a median of .225. The range of coefficients extended from .85 to − .38, as compared with a theoretical range from 1.00 to − .470.

From this limited amount of empirical evidence certain tentative conclusions may be drawn. Their value is to some extent enhanced by the striking homogeneity of tendency revealed by all eight samples.

1. The average value of the empirically obtained r_{ab} corresponds closely to the value demanded by the equation, the mean difference in the eight samples being .0007.

2. Any particular value of r_{ab} may deviate from its average value by an amount equal to $1.00 - r_{ab}$, approximately.

3. The distribution of the r_{ab} values tends to be slightly skewed positively, negative deviations of relatively small amount occurring more frequently than larger positive deviations. In appearance, the curve of distribution resembles the blade of a propeller, with the narrow end turned toward the + 1.00 end of the distribution.

4. In a way the most interesting feature of the investigation is found in the relation of the probable error of the coefficient to the probable error of the distribution. It will be recalled that the probable error of the coefficient as computed by the proper formula was invariably greater than the probable error of the distribution of the empirically obtained coefficients. On the average, the probable error of the coefficient is 1.38 times the probable error of the distribution. Whether a number so close to $\sqrt{2}$ has any significance must be left for further investigations to decide.

Part II

In the preamble to the first part of this paper it is stated that the formula $r_{ab} = r_{ag}r_{bg}$ can be expected to hold only when the g associated with a and the g associated with b are identical, that is, indicate the same quality, or function, or standard, or criterion. Can the equation

be rewritten in such a way as to give a true answer when the g associated with b is different, in whole or in part, from the g associated with a?

To obtain an answer to this question, recourse was had to a different kind of material, this time personality ratings. In these ratings the setup was the same as before, ten persons twice rating each of the ten, including the self, on a series of traits. If two of the traits in question prove to be the same quality, then the simple formula will work, for the only condition preventing a perfect correlation is the errors of measurement. These errors spread through the measurements of both characteristics and, when the traits are correlated, the errors should in the long run reduce the r_{ab} value by an amount proportional to the reduction of the r_{ag}, r_{bg} values.

If the ratings of ten persons are performed twice by each of the ten, the result is 20 ranks for each person. If these 20 ranks are averaged and each person is assigned a final rank in terms of the magnitude of the average of the positions assigned him, these final ranks indicating consensus of opinion may be called g. When each of the 20 measurements is correlated with g, their average may be called r_{ag}. Similarly, if each of the 20 measurements is correlated with each of the others, the average of the 190 coefficients may be called r_{aa}. In this case does the special form of the Spearman formula, $r_{aa} = r^2_{ag}$, hold? It does within the necessary limits. Some other trait, b, may also be investigated in this way, and it is found that $r_{bb} = r^2_{bg}$. What now will be the correlation between traits a and b? If the same g is common to both, the original formula will give the answer. If, however, the g's are different, the r_{ab} will be lower than when the g's are alike. It may drop to zero or assume negative values, depending upon the relation between the g's. The correlation between a and b will then depend upon two factors: first, the relation between the two g's; second, the reduction from the true value caused by the random errors.

Since it is difficult, if not impossible, to find two human characteristics having exactly the same g, subterfuge must be resorted to in order to find identical g's. This may always be accomplished by holding the standard or criterion constant. To do this, the ranks assigned the person in first position in trait A are compared with the person assigned first position in trait B, the second in A is compared with the second in B, and so on. In this way $r_{gg'} = 1.00$, and the formula

will work. In two samples taken at random the following values were obtained: $r_{ag} = .713$, $r_{bg} = .372$, $r_{ab} = .273$, whereas the formula value of r_{ab} is .265, a discrepancy of .008. In the other sample $r_{ag} = .714$, $r_{bg} = .402$, and $r_{ab} = .297$, with a formula value of .300, a discrepancy of .003.

If the individuals instead of the criterion are held constant, what happens? To hold the individuals constant, the ten persons are arranged in any standard order, such as alphabetical. The correlation is worked by comparing the scores of the same individuals on the two tests. When this is done with the two samples already given, the r_{ag} and r_{bg} values remain the same as in the previous case, but the r_{ab} values fall to .124 and .130, respectively. Why does this happen?

The r_{ag}, r_{bg} terms show the decrease in magnitude of the coefficient which can be attributed to random errors. Further decrease can be accounted for by the fact that the two qualities measured, instead of being identical, are to some extent diverse. The extent of the diversity can be determined by solving the proportion r_{ab} (individuals constant) : r_{ab} (criteria constant) = x : 1.00. In the first sample this becomes .142 : .273 = x : 1.00, giving $x = .520$. In the second sample $x = .438$. Since x in both cases represents the relation between the qualities associated with a and b respectively, it may be given a value as a coefficient of correlation and the symbol $r_{gg'}$.

Since the magnitude of any r_{ab} is determined by the effect of the random errors and also by the relation between the qualities measured, it would appear that the Spearman formula is a special case of a more generalized one, one in which $r_{gg'} = 1.00$. The more general equation should provide for situations in which $r_{gg'}$ is less than unity. Such a formula is given in the following expression

$$r_{ab} = r_{ag}r_{bg'}r_{gg'}.$$

Since interest attaches usually to the relation between qualities rather than to the size of the raw coefficient, the formula may be rewritten

$$r_{gg'} = r_{ab}/r_{ag}r_{bg'}, \text{ or}$$
$$r_{gg'} = r_{ab}/(r_{aa}r_{bb})^{\frac{1}{2}}$$

The second formula is safer to use than the third, for correlated errors are prone to appear in retests and magnify r_{aa} and r_{bb} coefficients, whereas they have but slight effect upon r_{ag} and $r_{bg'}$ values.

Part III

When the rank-difference method is used, as in the illustrations given above with ten items and twenty tests or measurements, the number of separate coefficients that must be computed is as follows:

$$\begin{aligned} r_{ag} &= 20 \\ r_{bg} &= 20 \\ r_{aa} &= 190 \\ r_{bb} &= 190 \\ r_{ab} &= 400 \\ \text{Total} &= 820 \end{aligned}$$

At the rate of two a minute the work would take nearly seven hours. Any method which will shorten this labor should be thankfully received, especially by those who use the rank-difference method to any considerable extent. The remainder of this paper will be devoted to an exposition of the method.

The first step is to make a scatter table showing the number of times each item is placed in first, second, third, fourth, . . . tenth place if n is equal to ten.

Secondly, compute the mean of all the positions assigned each item, calling the smallest mean 1, the next 2, and so on.

Thirdly, prepare a new table in which the original table may be rearranged and staggered in accordance with the plan to be revealed. When n is 10, the maximum possible error is 9 places. The error may be either positive or negative. It is necessary to provide on the y-axis 19 rows extending from -9, through 0, to $+9$. For the item put in first place by either the criterion or the group average the 1 values show a deviation of 0 from the true position. Each 2 that the item in first place receives constitutes a positive difference of 1 place. Similarly, a 3 is a positive difference of 2 places, and so on until 10 is reached, in which case there is a positive difference of 9 places.

For every 1 that the item in second place receives, the difference equals -1; for each two, the difference is 0; for every 3, the difference is $+1$; and so on. By staggering the original table in such a way that all differences of 0 appear in the same row, all differences of -1 in the row above, and of $+1$ in the row below the 0-row, and so on for the other differences, the frequency of each difference may be

TABLE I

THE STEPS IN COMPUTING THE CORRELATION WITH A CRITERION

A. Original Table

	1	2	3	4	5	6	7	8	9	10
1	12	5	1	2	..	..	..	..	..	..
2	5	7	1	3	3	..	..	..	1	..
3	1	3	7	1	4	..	1	2	1	..
4	..	3	5	2	4	2	2	..	1	1
5	1	1	1	4	1	5	3	2	..	2
6	..	1	1	2	3	5	2	4	2	..
7	1	..	1	4	..	3	4	3	3	1
8	..	..	2	..	3	4	2	6	3	..
9	..	..	1	1	2	..	5	2	7	2
10	..	..	..	1	..	1	1	1	2	14
Sum	20	20	20	20	20	20	20	20	20	20

NOTE — The sum of each column and of each row must equal N or 20.

B. Staggered Table

d	1	2	3	4	5	6	7	8	9	10	Nn	dNn	d^2Nn
− 9	..	..	..	..	..	..	..	..	..	..	...	..	...
− 8	..	..	..	..	..	..	..	..	..	..	...	..	...
− 7	..	..	..	..	..	..	..	..	1	..	1	7	49
− 6	..	..	..	..	..	..	..	..	1	1	2	12	72
− 5	..	..	..	..	..	..	..	2	1	2	5	25	125
− 4	..	..	..	..	..	..	1	..	..	..	1	4	16
− 3	..	..	..	2	3	..	2	2	2	1	12	36	108
− 2	..	..	1	3	4	2	3	4	3	..	20	40	80
− 1	..	5	1	1	4	5	2	3	3	2	26	26	26
0	12	7	7	2	1	5	4	6	7	14	65	0	0
+ 1	5	3	5	4	3	3	2	2	2	..	29	29	29
+ 2	1	3	1	2	..	4	5	1	..	..	17	34	68
+ 3	..	1	1	4	3	..	1	..	..	..	10	30	90
+ 4	1	1	1	..	2	1	..	..	..	..	6	24	96
+ 5	..	..	2	1	..	..	..	..	..	..	3	15	75
+ 6	1	..	1	1	..	..	..	..	..	..	3	18	108
+ 7	..	..	..	..	..	..	..	..	..	..	...	..	...
+ 8	..	..	..	..	..	..	..	..	..	..	...	..	...
+ 9	..	..	..	..	..	..	..	..	..	..	...	..	...
Sum	20	20	20	20	20	20	20	20	20	20	200	0	942

$$r = 1.00 - \frac{\Sigma d^2Nn}{1/6N\ n(n^2 - 1)}$$
$$= 1.00 - 942/3300$$
$$= + .713$$

cumulated and entered at the right of the table. Since the formula calls for Σd^2, this column of frequencies may be multiplied by the corresponding d^2 and these numbers added to give Σd^2. The frequency is determined in the situation given above by both the number of items (n) and the number of measurements (N). In the Spearman formula $N = 1$. Consequently, in this modification the denominator of the fraction must be multiplied by N or the numerator divided by N. With this slight adjustment the rank-difference formula may be applied to scatter tables assembled from rank-difference material. A sample, showing the necessary steps, is given in Table I.

TABLE II

THE DISTRIBUTION OF TRAITS A AND B

Trait A

	A	B	C	D	E	F	G	H	I	J
1	..	..	5	..	12	..	2	..	1	..
2	..	..	7	..	5	1	3	3	1	..
3	1	..	3	..	1	1	1	4	7	2
4	2	1	3	2	..	1	2	4	5	..
5	3	2	1	5	1	..	4	1	1	2
6	2	..	1	5	..	2	2	3	1	4
7	4	1	..	3	1	3	4	..	1	3
8	2	..	..	4	..	3	..	3	2	6
9	5	2	..	..	..	7	1	2	1	2
10	1	14	..	1	..	2	1	..	..	1

Trait B

	A	B	C	D	E	F	G	H	I	J
1	3	5	2	..	3	2	2	2	..	1
2	..	1	4	1	8	2	..	4	..	..
3	2	..	1	1	1	4	..	3	4	4
4	1	2	2	3	4	2	1	3	2	..
5	1	1	5	3	..	1	2	3	1	3
6	4	1	1	4	2	1	4	2	..	1
7	1	..	1	3	1	1	2	2	2	7
8	5	2	1	3	..	4	2	..	3	..
9	2	2	3	1	1	1	3	1	5	1
10	1	6	..	1	..	2	4	..	3	3

To work the correlation between two different traits, the procedure is simply an extension of the principle already given. The scatter tables for the two traits should, for convenience, be written one immediately below the other, as shown in Table II.

Whenever an individual is given a first place in trait A and also in trait B, the difference between the two ranks is 0. To find the number of zero differences for those put in first place in both traits by some of the raters, multiply the number of entries in the top row of each table. This proves to be $(5 \times 2) + (12 \times 3) + (2 \times 2)$. The sum is equal to 50. In the staggered table this number is entered in column A in the zero-difference row. The entry in column A and opposite the + 1 value of d is obtained as follows. Multiply each entry in A row 1 by each corresponding entry in B row 2, thus: $(5 \times 4) + (12 \times 8) = 116$. To obtain the entry in column A opposite + $2d$ multiply each number in A row 1 by the corresponding number in B row 3.

TABLE III

TABLE FOR DETERMINING THE CORRELATION BETWEEN TRAITS A AND B

d	A	B	C	D	E	F	G	H	I	J	Nn	Nnd	Nnd^2
− 9	...	..	..	..	..	..	..	..	..	80	80	720	6480
− 8	...	..	..	..	..	..	..	..	47	19	66	528	4224
− 7	...	..	..	..	..	..	..	24	24	15	63	441	3087
− 6	...	..	..	..	..	..	37	22	56	37	152	912	5472
− 5	...	..	..	..	..	26	18	61	32	25	162	810	4050
− 4	...	..	..	..	36	25	40	33	29	29	192	768	3072
− 3	...	..	..	31	23	47	31	46	39	15	232	696	2088
− 2	...	..	26	33	28	36	35	39	34	46	277	554	1108
− 1	...	43	38	45	37	50	53	69	62	37	434	434	434
0	50	82	58	42	43	49	48	40	33	97	542	0	0
+ 1	116	29	40	46	57	60	54	30	44	..	476	476	476
+ 2	21	50	44	37	46	41	37	36	..	..	312	624	1248
+ 3	62	52	24	34	46	32	47	..	..	..	297	891	2673
+ 4	30	36	44	44	39	34	..	..	..	..	227	908	3632
+ 5	37	27	35	53	45	..	..	..	..	..	197	985	4925
+ 6	23	20	57	35	..	..	..	..	..	..	135	810	4860
+ 7	12	44	34	..	..	..	..	..	..	..	90	630	4410
+ 8	38	17	..	..	..	..	..	..	..	..	55	440	3520
+ 9	11	..	..	..	..	..	..	..	..	..	11	99	891
Sum											4000	0	56650

$$r = 1.00 - 56650/66000$$
$$= + .142$$

For column B with the $-1d$ row multiply each number in row 2 of Table A by the corresponding numbers in the first row of Table B, as $(7 \times 2) + (5 \times 3) + (1 \times 2) + (3 \times 2) + (3 \times 2) = 43$. The zero difference for column B of the staggered table is obtained by multiplying each entry in row 2 of Table A by each corresponding entry in row 2 of Table B.

The entire staggered table is presented in Table III, showing all entries and the steps necessary for computing the correlation coefficient. This coefficient proves to have a value of $+ .142$.

To obtain the reliability coefficient the procedure is exactly the same as in the preceding case except that, as a visual aid, the table for trait A should be written twice. If the second table is called B, the previous description for obtaining the correlation between A and B may be followed exactly.

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AN INVESTIGATION INTO THE NATURE OF ENCEPHALITIS NEONATORUM

ARTHUR L. AMOLSCH

IN 1866 Virchow (3) interpreted degenerative and infiltrative alterations in the cerebrum of newborn infants as manifestations of an inflammatory reaction which he chose to designate by the term "encephalitis congenita." Subsequently, other investigators have questioned the complete accuracy of such an explanation, basing their contention chiefly on the significance of intracellular and extracellular lipoid deposits in the brains of such cases. One school of thought has maintained that the fat is a manifestation of degenerative changes. The opponents have insisted that such fat is present in the brains of all newborn infants and is definitely related to physiologic and developmental changes associated with the process of myelenization. This controversy has continued intermittently to the present time.

Later Virchow (4) receded somewhat from his first opinion and admitted that phases of the reaction need not necessarily be an expression of a true inflammation. Nevertheless, he was inclined to associate the process with infection or possible toxic action.

By concentrating upon the significance of these lipoid changes it appears that the inflammatory exudative feature of so-called encephalitis congenita has been somewhat neglected. However, in 1920 Ceelen (1) described exudative and degenerative changes in a series of twenty brains of newborn infants. This author attempted to correlate the process in several of his cases with omphalitis neonatorum. His description of the perivascular infiltrations beneath the ependyma, and particularly his statement that these cellular aggregates tend to assume a sector localization with reference to the blood vessels, substantiates our opinion that the cellular changes which Ceelen and many others have interpreted as exudative can be demonstrated in the brain of any infant at or near term.

Whatever the consensus of European opinion may now be relating to the suggestively exudative nature of this process, it is evident that the majority of local histopathologists are almost wholly concerned with these features when rendering a diagnosis of encephalitis congenita.

In this discussion we are solely concerned with the significance of these so-called exudative features. The cellular reactions in question are usually demonstrated in subependymal position, and in chance autopsy sections are characterized either by a zone of small round or oval cells or by more definite localization of such cells, at times slightly elevating the ependyma, and at times forming a larger granulomatous-appearing mass. The microscopic feature which is most misleading is a perivascular mantle of deeply stained round or slightly elongated cells found about the subependymal veins and at times more remotely in the fiber tracks.

Plates LV–LVI illustrate the gross and microscopic features of neurogenic activity in a 32-week foetus.

The author's interest in this condition was primarily established by contact with four instances of prominent subependymal infiltration and proliferation in the brains of infants in which massive intraventricular hemorrhage was demonstrated shortly after birth. The first impression was that of fetal encephalitis. Subsequent study suggested that a prominent glioblastic proliferation was associated with the hemorrhage in three of these cases, whereas the fourth case seemed to be an example of a true glioblastoma.

The second phase of this investigation was conducted with the kind coöperation of Dr. C. V. Weller, of the University of Michigan Medical School. During an examination of cerebral tissues from fifty-five autopsies on newborn infants it was possible to demonstrate to some degree the presence of this supposed inflammatory infiltration beneath the ependyma in thirty-two cases. This high incidence of encephalitis neonatorum suggested an error in the interpretation of the morphologic picture. An examination of the maternal records showed that only eight mothers presented direct or indirect evidence of infection during the pregnancy under question. Moreover, the cerebral changes in these eight cases were no different in character or extent from those demonstrated in the twenty-four uninfected cases. It was also noteworthy that no inflammatory infiltration was demonstrated in the cerebral cortex, the meninges, or the choroid

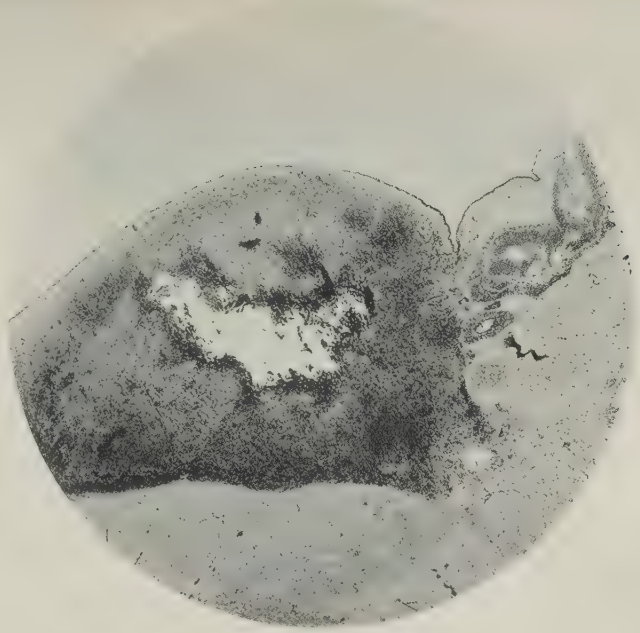

FIG. 1. The large sharply defined granulomatous-appearing mass of neurogenic cells in the angle between the caudate nerve and the thalamus of a 32-week fetus. The perivascular mantles are seen in the upper right quadrant. Central hemorrhage and tissue destruction. Magnification: 32 mm. microtessar; bellows length, 50 cm.

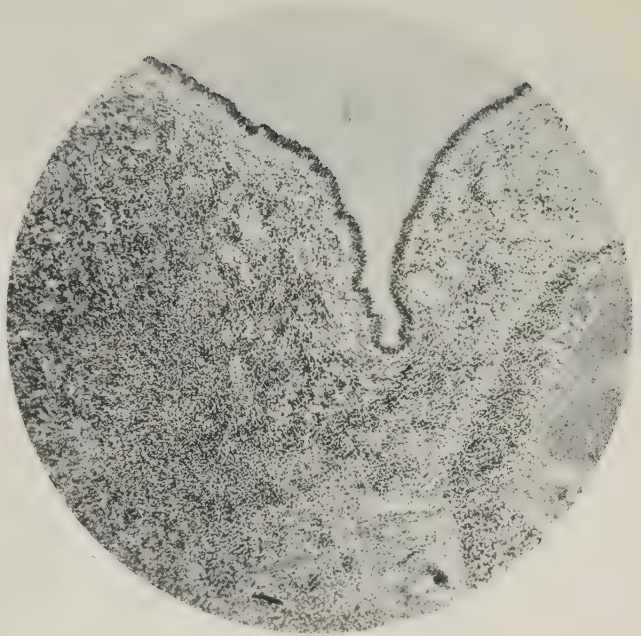

FIG. 2. The area near the slight ventricular recess shown in Figure 1. Perivascular mantle at the right. Hemorrhage and tissue destruction at the left. Small aggregates of intensely stained small round and slightly elongated cells in the center. Magnification: 16 mm. obj.; 7.5 oce.; bellows length, 55 cm.

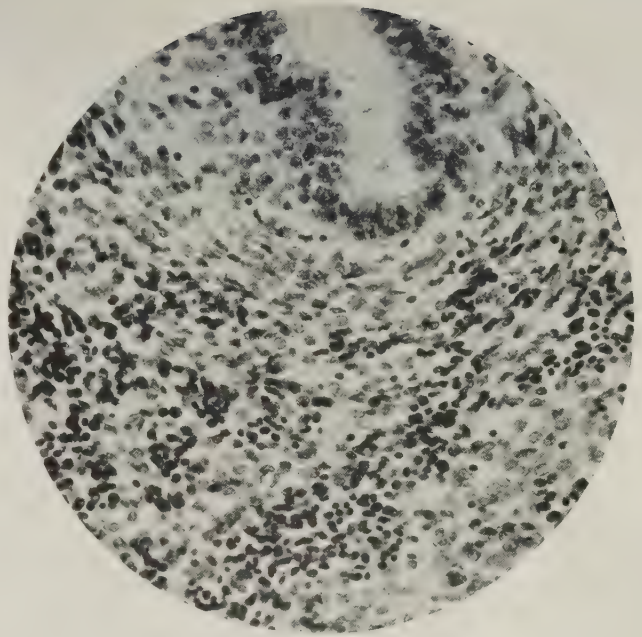

FIG. 1. The same area as that shown in Plate LV, Figure 2. Note the groupments of primitive neurogenic cells with round or slightly elongated nuclei. Magnification: 4 mm. obj.; 7.5 occ.; bellows length, 55 cm.

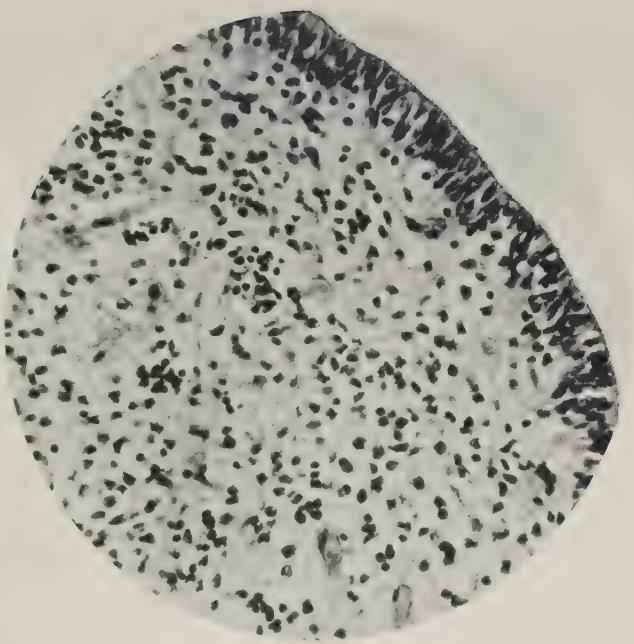

FIG. 2. An area of less prominent neurogenic activity slightly removed from the main focus. Small groupments of differentiating cells in a loose glial tissue stroma. Magnification: 4 mm. obj.; 7.5 occ.; bellows length, 85 cm.

plexus, and examination of other organs failed to reveal any inflammatory reaction other than pneumonia in a few instances of this series. Such circumstances all tend to indicate that the process is not inflammatory in nature, but is associated with developmental changes in the cerebrum.

The third phase of this study, which at the moment is incomplete, consists of the examination of the brains of fetuses of various stages of development and of newborn infants of approximate term development. This series now consists of a group of twenty-two brains, of which six represent 12 to 18 weeks' development, two are in the 19- to 26-week period, three in the 27- to 35-week period, four in the 36- to 39-week period, and five are brains of term infants, none of which lived longer than three days.

Coronal sections of these brains were made at intervals of 6 to 8 mm. throughout the ventricular system, for the purpose of determining the location and the degree of the developmental activity at varied stages of growth. The following deductions are based on this study:

1. Subependymal neurogenic activity is present in all brains of the series.

2. The intensity and the extent of the developmental activity are directly proportionate to the degree of immaturity.

3. The character of the reaction and the nature of the cells are the same as those observed in chance autopsy sections when the diagnosis of encephalitis neonatorum has usually been made.

The misinterpretation of cellular changes in the newborn brain has its basis in the distinctive migratory and invasive character of primitive neurogenic cells which are small, round, or slightly ovoid in shape, poor in cytoplasm, and possess nuclei which stain intensely. The term "neurobiotaxis" was used by Kappers (2) to designate the migratory and invasive nature of ganglionic tissue evolution. Neurogenic activity has become quiescent at the end of the third fetal month in the spinal cord, medulla, and pons, which, phylogenetically and ontogenetically, are the oldest structures of the central nervous system.

In the group of brains examined in this study it is noted that neurogenic activity has ceased in relation to the third ventricle and aqueduct of Sylvius, and is very slight in the region of the fourth ventricle in the most immature brains. The process which ordinarily attracts the attention of the pathologist is observed as a rule in fetuses

of at least six months' development, and is an expression of the development of the neostriatum and communicating tracks.

With the ordinary staining methods employed in this preliminary study it is impossible to recognize all the intermediate types of primitive neuroblastic cells which undoubtedly are present in the field of cellular proliferation. It is possible that some of the small round cells, which are found about the blood vessels, are derived from mesodermic elements. Granting the truth of this supposition, it does not follow that their presence is proof of inflammation, since cells of this type are found in mature organic tissues, such as mammary gland and endometrium when those glands are reacting hyperplastically to growth stimuli.

We are all aware of the previous tendency on the part of the pathologist in the not too remote past to render a diagnosis of chronic mastitis or chronic endometritis upon finding migratory round cells in the essential stroma of these glandular tissues when they are responding normally or abnormally to hormone stimulation. We feel that a somewhat analogous situation is present during the active stages of cerebral differentiation, complicated, however, by the natural invasive and infiltrative character of neurogenic proliferation during development.

CONCLUSIONS

1. Subependymal cellular infiltration of small round cells and perivascular mantles of such cells, found in the brain of the newborn, are not to be interpreted as an expression of encephalitis. It is definitely developmental in nature.

2. This reaction is most pronounced in the prematurely born infants which are stillborn or which live only a few weeks.

3. The most prominent manifestation of the incomplete state of cerebral development in the term or near-term infant is observed in the angle between the caudate nucleus and the thalamus, and at the upper lateral angle of the lateral ventricle in sections through the anterior half of the brain.

4. Our failure to interpret properly such manifestations rests upon an incomplete understanding of cerebral development, especially in relation to the formation of the neostriatum and the internuclear pathways.

5. It is admitted that encephalitis neonatorum *per se* can exist,

but such a diagnosis must depend upon the presence of a true inflammatory reaction; cellular changes which are associated with development must be excluded in making such a diagnosis.

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BIBLIOGRAPHY

1. Ceelen, W. Über Gehirnbefunde bei Neugeborenen und Säuglingen (Encephalitis Congenita, Virchow's). Virchows Arch., Bd. 227, Heft 2, pp. 152–167. 1920.
2. Kappers, C. U. Ariens. Further Contributions on Neurobiotaxis. Journ. Comp. Neurol., 27: 261–298. 1917.
3. Virchow, R. Über interstitielle Encephalitis. Arch. f. path. Anat . . ., Bd. 44, pp. 472–476. 1868.
4. —— Berl. klin. Wochenschr., No. 46. 1883.

LABORATORY DIAGNOSIS OF SYPHILIS *

OSBORNE ALLEN BRINES

IN AN attempt to obtain some information regarding the efficiency of laboratory diagnostic methods in syphilis a survey covering a period of one year (1934) was made at the Receiving Hospital, Detroit. During this period the disease was studied from the serological and the pathological aspects.

PURPOSES

1. To determine the relative practical value and specificity of tests employed;
2. To compare the incidence of syphilis in a general hospital (*a*) from a serodiagnostic viewpoint and (*b*) from a study of autopsy material;
3. To consider the matter of interpreting positive blood tests;
4. To evaluate syphilis as a general mortality factor.

MATERIAL

1. The routine examination of 23,668 blood specimens for their reaction to one or more of the following tests: (*a*) Kolmer, (*b*) Kahn, (*c*) Kline;
2. The performance of 618 autopsies.

CONDITIONS

1. A general hospital without an obstetrical or a pediatric service;
2. An age incidence of 42.7 years, which is slightly higher than those for most general hospitals;
3. A colored population of 36 per cent;
4. No attempt made to treat syphilis in the institution;
5. Nearly all syphilis in the tertiary stage;

* From the Laboratories of Receiving Hospital, Detroit, Michigan.

6. A large psychiatric service consisting of 30 per cent of all hospital beds, which would tend to increase the incidence because of the large number of paretics on this service;

7. Approximately the same percentage of autopsies (40 per cent) secured for medical, surgical, and special services, and somewhat lower (26 per cent) for psychiatric service; and with two thirds of all autopsies secured from the medical service;

8. All the laboratory tests performed by the same serologist;

9. Specimens of blood taken routinely on all hospital admissions.

HISTORY

Up to September 1, 1933, the Standard Kahn Test and a modified quantitative Kolmer test were performed routinely on all blood specimens. After a preliminary trial period the Kahn, Kline, and Kolmer tests were made on all blood specimens submitted from September 1, 1933, to January 1, 1934, a four-month period during which about 8,000 specimens were examined. It was found that, with rare and negligible exceptions, the Kline test was always positive whenever the Kahn and the Kolmer tests were positive. Therefore, we considered justifiable a procedure already followed in other institutions, namely, to employ the Kahn and the Kolmer tests only in cases which had exhibited a positive Kline reaction.

PRELIMINARY EXPERIENCE

During this four-month preliminary period we found that out of 8,000 specimens examined there were 886 which gave positive or doubtful Kline tests and which were negative for the other tests employed. In an attempt to evaluate positive results by the Kline method only, we decided to obtain clinical information from as many patients as possible by direct questioning. This was done in an impartial manner by one of the clinical residents. Of the 886 patients in this group only 247 were considered to be sufficiently coöperative for questioning, and of these 107, or 43.7 per cent, gave clinical or historical evidence of syphilitic infection. Seventy-five, or 69.4 per cent, of these had received antisyphilitic treatment. Of the 107 cases with positive histories or clinical findings, 72 had doubtful tests and 35 positive tests.

RESULTS

During 1934, 23,668 blood specimens were examined for syphilis. Of these, 3,350, or 14.2 per cent, were definitely positive. Inasmuch as the Kline test was usually the strongest, we insisted that a positive test should be at least two plus with the diagnostic antigen. If we admit the one plus and the plus–minus tests which we classified as doubtful, another 3,457 cases would be added to bring the percentage to 28.7.

During the same period 618 autopsies were performed. These cases were representative of the general hospital population. Approximately 14 per cent of the cases autopsied had positive serological tests for syphilis, but of the 84 necropsied cases with positive blood tests 45, or 53.6 per cent, showed no histopathological evidence of syphilis. With the doubtful tests in the necropsied cases added, there were 78 of 117 cases, or 66.6 per cent of cases with positive or doubtful tests which showed no gross or microscopical evidence of syphilis at autopsy.

Sixteen cases, or 2.6 per cent of the cases coming to post-mortem, had fatal syphilitic lesions, of which *seven* were cardiac (syphilitic aortitis with aortic insufficiency) and *nine* neurological. I have already called attention to the large number of paretics in this hospital. Of these fatal cases 12 out of 15, or 80 per cent, had positive serology and 3, or 20 per cent, were negative. There were 38 additional cases, or 6.1 per cent of all autopsies in which there was gross or microscopic evidence of syphilis, but in which syphilis was an incidental finding and not the cause of death. Of these 38 cases 31 had serological examinations, of which 27, or 87 per cent, were positive and 2 were doubtful. In the 46 autopsied cases with recognized syphilitic lesions in which blood tests were reported, 87 per cent had positive tests. This brings the total number of cases presenting histopathological evidence of syphilis at autopsy to 54, or 8.7 per cent of all autopsies. This is somewhat in contrast to the 14.2 per cent of all admissions and the 14 per cent of autopsied cases which had definitely positive blood tests. I presume, from the standpoint of the syphilologist at least, that we are to infer that the difference of 5.5 per cent (leaving doubtful tests out of consideration) represents latent syphilis which might produce no organic lesion, but which may become activated spontaneously. It must

be explained that syphilitic aortitis without valve involvement was invariably the lesion of nonfatal syphilis recognized, and its presence or absence was to a large extent the criterion observed in grouping these cases. There were doubtless a few early or mild cases of syphilitic aortitis which were not recognized in post-mortem study.

In contrast to the 45 cases at necropsy with positive serology and no pathological evidence of syphilis there were only 7 cases in which the reverse was true. There were 33 cases with doubtful serology and no tissue evidence of syphilis, whereas in only 4 cases was the reverse true.

Among the 23,668 blood specimens examined there were 204 in which the diagnostic Kline test was positive (two plus or more) and the Kolmer and the Kahn tests negative. There were an additional 2,069 in which the Kline test was doubtful (one plus or plus–minus with diagnostic antigen) and the other two tests were negative. According to our previous experience, we would be inclined to consider half of these cases as representing bona fide clinical syphilis.

By adding 2,446 specimens which gave positive reactions with the Kline exclusion antigen and the negative Kolmer and Kahn tests, a total is reached of 39.1 per cent of all blood specimens tested which gave positive, doubtful, or faint serological evidence of syphilis. Considering the 8.7 per cent of demonstrable syphilis at autopsy, such a figure would be quite ridiculous.

If we compare the sensitivity of the Kolmer and the Kahn tests, there were 448 which gave positive Kahn reactions (two plus or stronger) and negative Kolmer reactions. There were 54 specimens which gave positive Kolmer reactions (two plus or stronger) and negative Kahn tests.

DISCUSSION

There are findings reported here which are quite inconsistent and contradictory. They inspire confidence in the specificity of serological tests on the one hand and destroy it on the other. Over a four-month period 72 cases were encountered in which the diagnostic Kline test was doubtful (one plus or plus–minus), and in which clinical or historical evidence of syphilis was elicited. On the other hand, with the same test only 33.3 per cent of cases with positive or doubtful serology presented gross or microscopic evidence of syphilis. There may be several explanations:

1. The clinical information may have been collected unfairly and leading questions used in history taking.

2. Our methods of examining tissues at autopsy may not have been sufficiently fine to detect changes due to syphilis.

3. Benign tertiary syphilitic lesions are notably difficult to recognize by any method employed, and a great many tertiary syphilitic lesions would be missed in a routine prosection.

4. Latency in tertiary syphilitic infection may be more common than is generally supposed.

5. No special attempt was made to demonstrate syphilis at autopsy; this comparison was not contemplated until after the end of the year.

CONCLUSIONS

1. As a diagnostic laboratory procedure in syphilis, doubtful tests should probably be disregarded for practical purposes if laboratory tests are to correspond even approximately to autopsy findings.

2. Doubtful diagnostic tests and positive tests with the Kline exclusion antigen should as a rule be seriously considered only in checking treated cases.

3. In attempting to evolve a serological test which will detect between 80 and 100 per cent of syphilitic infection in the laboratory, extremely delicate tests have been developed which produce a large number of positive and doubtful reactions which cannot be correlated with clinical and autopsy evidence of syphilis.

4. These positive tests are not necessarily false positives, because the intangible element of latent syphilis must be considered.

5. A zone of nonspecificity probably exists between laboratory and clinical syphilis, the width of which is not fully appreciated.

6. We discontinued the Kolmer test at the end of 1934 because it could not be demonstrated that the complement fixation test is a valuable adjunct to the laboratory diagnosis of syphilis, considering the highly efficient flocculation tests available.

7. Syphilis as a present-day mortality factor must be exaggerated in the minds of both medical profession and laity when it is considered that only 2.6 per cent of a general hospital population died of syphilis, that more than half of these deaths were due to lesions of the central nervous system (owing to the fact that 30 per cent of the hospital census consists of psychopathic cases), and that essentially

none had been receiving active treatment. During the same period 73 cases of cancer came to autopsy as compared with 16 of syphilis.

8. Two questions must be asked: (1) Does this zone of 53.6 per cent, in which the blood test was positive and the autopsy findings were negative, represent latent syphilis? (2) If so, how serious is syphilitic infection which cannot be demonstrated by careful post-mortem examination?

Receiving Hospital
Detroit, Michigan

THE NUMBER OF EGGS PRODUCED AND LAID BY THE FOUR-TOED SALAMANDER, *HEMIDACTYLIUM SCUTATUM* (SCHLEGEL), IN SOUTHERN MICHIGAN *

FRANK N. BLANCHARD

APPARENTLY the only definite reference to the number of eggs produced by the salamander *Hemidactylium scutatum* is S. C. Bishop's quotation [1] from the manuscript of Julia Moesel to the effect that 53 ovarian eggs were found in one specimen and 57 in another. Bishop's own observation [2] of an average of about 50 eggs in field complements seemed to indicate that these counts were fair samples. In southern Michigan, however, although more than 200 salamanders have been dissected and their eggs counted, no female has been found with more than 46 mature eggs in her ovaries, and the number ranges down to six. Whether this is a real difference between the salamanders of the Ithaca and the Ann Arbor regions remains to be demonstrated by further data from the vicinity of Ithaca.

Specifically, total ovarian egg complements have been counted in 217 females collected in Washtenaw County, Michigan, and vicinity in the years 1923 to 1930. The results set forth graphically (Fig. 24, lower part) show the approximate range of variation in numbers of eggs produced by this species in this region. The lack of a well-marked single mode shows plainly that the collections on which the data were obtained represent a variety of conditions. For this reason the exact average of these counts, 29 eggs per female, has, probably, no great significance.

Counts of total egg complements from 50 natural nests (such as that shown in Pl. LVII, Fig. 1) that contained not more than 46 eggs (the upper limit of ovarian counts, Fig. 24, upper part) average

* Contribution from the Zoölogical Laboratory of the University of Michigan.

[1] *New York State Mus. Bull.*, Nos. 219, 220: 257. 1919.

[2] *Ibid.*, p. 258.

31.1 eggs per nest. However, since nests with more than 40 eggs (such as in Pl. LVII, Fig. 2) have a fair chance of comprising two or more complements [3] (observe diagrams in Fig. 24), the average obtained by excluding nests of more than 40 eggs may be more significant. This average, 27.8, is very close to that derived from counting

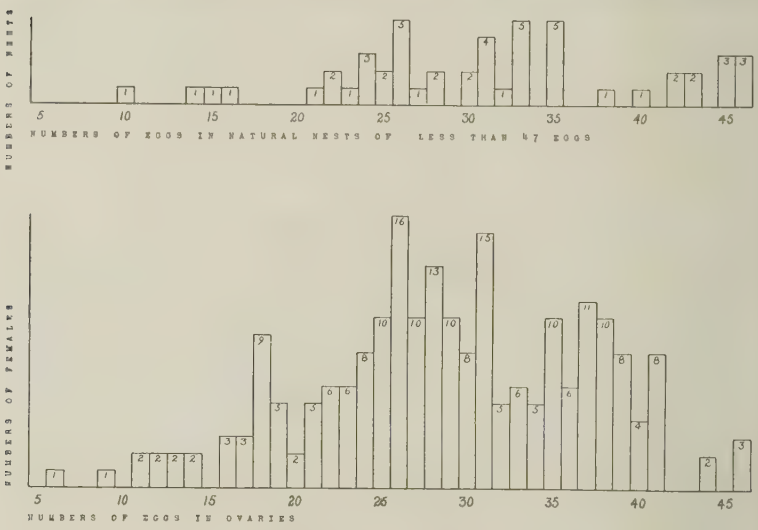

Fig. 24. Number of eggs in a complement of *Hemidactylium*

Upper figure: Numbers of eggs in natural nests containing fewer than 47 eggs. The average is 31.1 eggs per nest. If nests of more than 40 eggs are excluded from consideration as possibly comprising two complements, the average, 27.8, is very close to that obtained from ovarian counts

Lower figure: Counts of ovarian eggs in 217 females collected in various habitats and years. Average, 29 eggs per female

ovarian complements, i.e. 28.9 eggs per female. The difference between these two averages contains its probable error only one and one-half times, while the difference between the average of the ovarian counts and that of all natural nests of fewer than 47 eggs contains its probable error two and one-third times. This bears out the suggestion made above, from inspection of the diagrams in Figure 24, that nests of fewer than 41 eggs are generally produced by single females, and that nests of 41 to 46 eggs are sometimes due to two females.

[3] Blanchard, F. N., "The Relation of the Female Four-toed Salamander to Her Nest," *Copeia*, No. 3: 137–138. 1934.

FIG. 1. Typical nest of *Hemidactylium* containing only one complement of eggs. The attendant female and most of the eggs are shown undisturbed by parting and pushing aside the moss

FIG. 2. Typical large nests of *Hemidactylium*, each containing eggs of two or more females. Head of the single attendant female shows in center of left-hand nest. In right-hand nest the female shows near center, with her head extending obliquely down at left of tail

For convenience and completeness the figures relating to average egg complements are summarized in Table I.

TABLE I

Summary of Average Egg Complements

1. Fifty nests containing fewer than 47 eggs average 31.100 ± 0.861 eggs per nest.
2. Dissections of 217 females average 28.940 ± 0.363 eggs per female.
3. Forty nests containing fewer than 41 eggs average 27.800 ± 0.703 eggs per nest.
4. The difference between (1) and (2) is 2.160 ± 0.934.
5. This difference contains its probable error 2.3 times.
6. The difference between (2) and (3) is 1.140 ± 0.791.
7. This difference contains its probable error 1.4 times.

From this discussion and summary (Table I) it appears (on account of the close correspondence between the average number of eggs in natural nests of fewer than 41 eggs and the average of ovarian counts) that (1) all the eggs produced by the ovaries are ordinarily deposited; (2) they are deposited in a single nest (that is, the female does not lay part of her eggs in one nest and part in another); and (3) usually a nest of fewer than 41 eggs is the product of a single female.

That all the eggs produced are ordinarily deposited is borne out by dissections of spent females. Most of such females have no eggs in ovaries, body cavity, or oviducts. But in the large series of spring females dissected cases of failure to shed some of the eggs have been noted. From one to several eggs have sometimes been found degenerating in the ovaries long after the other eggs had been laid and, rarely, degenerating eggs have been found in the body cavity. One female, collected on May 28, had at least nine such eggs in the coelom. There is no evidence that a few eggs are normally left in the body cavity after spawning, owing to the inefficiency of the mechanism for getting them into the funnels of the oviducts, as B. G. Smith [4] found to be the case in *Cryptobranchus*.

The average total egg complement may vary from one season to another in the same habitat. Thus, two rather large collections from Whiteoak vary markedly, and apparently significantly, in the two

[4] "The Process of Ovulation in Amphibia," *Ann. Rep. Mich. Acad. Sci.*, 18: 104. 1916.

TABLE II

SUMMARY OF MEAN TOTAL EGG COMPLEMENTS FROM VARIOUS LOCALITIES AND SEASONS

Locality	Date of collection	Number of specimens	Mean total egg complement and probable error	Difference between means and probable error of difference	Number of times difference contains its probable error
Whiteoak.....	April 21, 1923	41	28.780 ± 0.685	6.173 ± 0.900	6.9
"	" 18, 1930	56	22.607 ± 0.583		
Hamburg.....	" 20, 1924	47	33.00	.....	...
Iosco.....	Nov. 9, 1924	10	32.00 ± 1.33	1.29 ± 1.57	0.8
"	April 5, 1925	7	30.71 ± 0.83	5.93 ± 0.95	6.2
"	Oct. 17, 1926	11	36.64 ± 0.45		
Cady's Woods.	April 20, 1923	8	27.13 ± 2.09	7.73 ± 3.37	2.3
Freedom.....	" 19, "	7	34.86 ± 2.65		

TABLE III

SUMMARY OF NUMBERS OF EGGS PRODUCED BY LEFT AND RIGHT OVARIES

Number of specimens in collection	Average number of eggs	
	Left ovary	Right ovary
41	14.0	14.8
56	11.2	11.4
47	15.9	17.1
10	15.4	16.7
7	15.0	15.7
11	17.4	19.3
8	13.6	13.5
7	17.3	17.6

Total number of specimens dissected...	217
Mean number of eggs in left ovaries....	14.157 ± 0.207
Mean number of eggs in right ovaries...	14.687 ± 0.204
Difference between these means.....	0.530 ± 0.29
Number of times this difference contains its probable error.....	1.9

seasons 1923 and 1930 (Table II). The higher egg production of 1923 is related to precipitation favorable to amphibian life, whereas the lower figure of 1930 is correlated with the unusually dry autumn of 1928 and year of 1929. Likewise the collections at Iosco (Table II),

made in the spring of 1925 and the autumn of 1926, although small, seem to be significantly different. It is worthy of notice that the collections made at this place in the autumn of 1924 and the ensuing spring are practically identical, when their probable errors are taken into account. They should be, of course, but that they are demonstrably so in such small collections lends weight to the difference shown in the two different seasons (1925 and 1926) at this place.

The present data do not lend themselves to a demonstration of differences in egg production between two different habitats in the

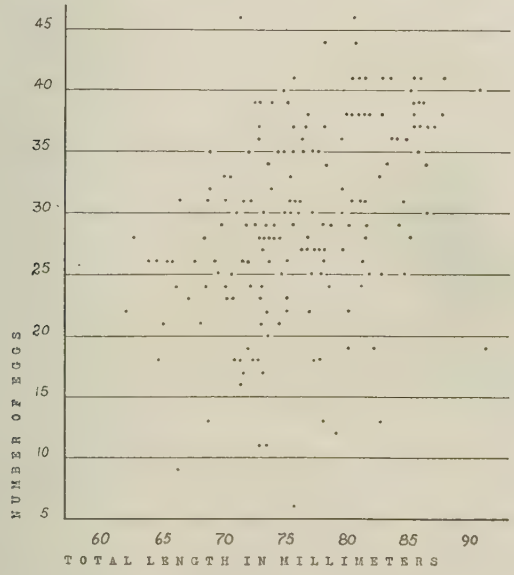

Fig. 25. Diagram showing relation between total length of female *Hemidactylium* and number of eggs produced. Each dot represents one female and her egg complement

same season. If the difference between Cady's Woods and Freedom (see Table II) is a real one the collections are too small to show it.

There is some evidence that the larger females lay, on the whole, more eggs than the smaller ones. This is brought out graphically in Figure 25, where each egg complement is plotted against the total length of the female that produced it. It was necessary, of course,

to reject all records based on females with shortened or regenerated tails. But to answer this question satisfactorily data should be obtained on about two hundred females collected in the same locality and in the same year; for, as pointed out above, there may be a real

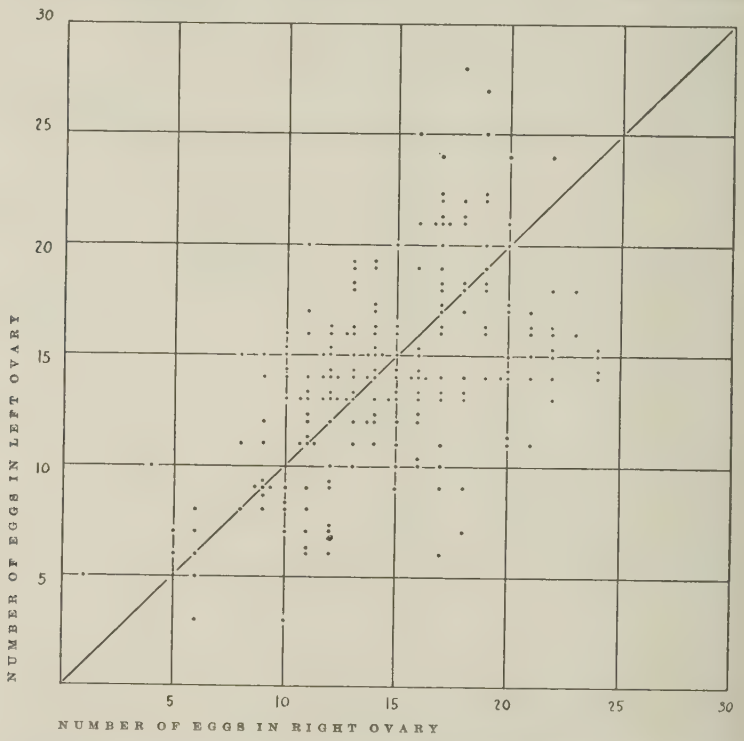

FIG. 26. Diagram showing variation in egg production between right and left ovaries, based on 217 dissections. Each dot shows the number of eggs in a left ovary and in its corresponding right one

difference between different seasons, and between some habitats in the same season. There is not likely, however, to be an early opportunity to obtain such a series.

A comparison of egg production of left ovaries with that of right shows that the number of eggs in one ovary is often identical with that in the other, but that it is more often different, and sometimes markedly different. To determine whether there is any real difference

between the ovaries, the average number of eggs in each has been tabulated separately for the principal collections (see Table III). Seven of the eight collections show a slightly greater egg production by the right ovary. However, the average of all the collections, together with thirty specimens taken at various times and places, shows an average difference of only half an egg in favor of the right ovary, a difference that is presumably of no significance, since it is less than twice its probable error (Table III). The Pearson linear correlation coefficient between the numbers of eggs in right and left ovaries is 0.46. This shows a degree of dependence in number of eggs between the two ovaries, but not so much as might be expected from the close correspondence between the means. This is visibly evident in the scatter diagram, Figure 26.

SUMMARY

1. In southern Michigan the salamander *Hemidactylium* produces ordinarily from 18 to 41 eggs per female. The minimum count found in 217 specimens is 6; the maximum, 46.

2. Normally all the eggs produced by the ovaries are laid, but sometimes a few remain in them and, rarely, in the body cavity.

3. Larger females lay, on the whole, more eggs than smaller females, but there is much variation.

4. A female lays all her eggs in the same nest.

5. A natural nest containing fewer than 41 eggs is probably the product of a single female; more than 46 eggs are probably due to two or more females.

6. The number of eggs produced by the females of a single habitat may vary significantly from one season to another.

7. Although there may be considerable variation in egg production between the two ovaries of a single individual there is no demonstrable difference in this respect in the population as a whole.

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FAMILIES OF THE SPIDERS OF MICHIGAN

ARTHUR M. CHICKERING

DURING the past seven years I have been collecting spiders from the State of Michigan. Several lists of these animals published during the last four years give the results of this work as it progressed (Chickering, 1932–35). Additions, thus far unpublished, have been made to the number of identified species until I now have more than three hundred in my collection. Twenty-one families of spiders are now recognized in Michigan according to my present system of classification, which is only slightly modified from that of Petrunkevitch's *Systema Aranearum* (1928). All these families are well represented except the Dysderidae, which have not been found here, but are included because of their expected occurrence, and the Oecobiidae, of which but one immature specimen has been taken in the state.

As a foundation for further work on the genera and species of the spiders of Michigan and as an aid to those who may wish to gain some knowledge concerning this very interesting group of animals, a key to the families native to the state is here provided, together with simple descriptions of each family. It has been pointed out elsewhere (Chickering, 1933) that spiders offer convenient material for biological study with grade school children and high school students. An attempt, therefore, has been made in this paper to provide a key, accompanied by simple figures, which will make it possible for teachers and older students to separate these groups with a minimum of difficulty. In spite of this effort beginning students probably will find places in the key where it will be difficult to make a decision. There is no complete remedy for this, but reference to more extended treatises will furnish the best aid. A brief glossary of terms used to separate the families is included as a further aid to beginners, together with a general outline of classification of our Michigan spiders and a simple diagnosis of each family.

KEY TO THE FAMILIES OF THE SPIDERS OF MICHIGAN

1. With a cribellum and a calamistrum (Figs. 13–15) 2
1. Without a cribellum and a calamistrum 5

2. Cribellum divided by a keel (often delicate and difficult to see) 4
2. Cribellum not divided by a keel 3

3. Eyes all dark; posterior metatarsi with a series of ventral spines *Uloboridae*
3. Eyes heterogeneous, with only anterior medians dark; posterior metatarsi without a series of ventral spines ..... *Dictynidae*

4. Eyes crowded near the center of the cephalothorax; second segment of posterior spinnerets elongated ..... *Oecobiidae*
4. Eyes in anterior region of cephalothorax; second segment of posterior spinnerets short ..... *Amaurobiidae*

5. Tibiae and metatarsi of first two pairs of legs with long prolateral spines, between which are rows of shorter spines (Fig. 16) ..... *Mimetidae*
5. Tibiae and metatarsi of first two pairs of legs without such spines, as in Mimetidae 6

6. Fourth tarsi with a ventral row of serrated spines forming a comb (Fig. 8) ..... *Theridiidae*
6. Fourth tarsi without a ventral row of serrated spines forming a comb .. 7

7. With only six eyes 8
7. With eight eyes 10

8. With two tracheal spiracles on the ventral surface of the abdomen just posterior to the lung slits (Fig. 4) ..... *Dysderidae*
8. With one tracheal spiracle on the ventral surface of the abdomen just in front of the spinnerets (Fig. 1) 9

9. With very long legs and chelate chelicerae (Fig. 10). Part of the Pholcidae (Spermophora) ..... *Pholcidae*
9. With legs of the usual length and uncate chelicerae (Fig. 9) .... *Sicariidae*

10. Tarsi with only two claws (Figs. 5, 7) 11
10. Tarsi with three claws (Fig. 6) 15

11. Eyes in three rows; first row composed of four eyes, of which the medians are always by far the largest; second and third have two eyes each, those of the second row being the smallest (Fig. 19) ..... *Attidae*
11. Eyes in two rows, as in Figure 20 12

12. Legs laterigrade or crablike. (Care must be taken in identifying Tibellus, which does not show the crablike form so clearly) ..... *Thomisidae*
12. Legs prograde, as in the majority of spiders 13

13. Fore spinnerets widely separated. Maxillary lobes (Fig. 1) usually depressed obliquely transverse ..... *Drassidae*
13. Fore spinnerets close together. Maxillary lobes not depressed transversely 14

14. Furrow of posterior spiracle near the middle of the abdomen (Fig. 3) *Anyphaenidae*
14. Furrow of posterior spiracle in the usual position near the spinnerets *Clubionidae*

15. Trochanters with a distinct, deep, bordered, semicircular notch on the ventral side at the distal end (Fig. 12) 16
15. Trochanters without such a notch or with only a slight one 17

16. Eyes in three rows; four small eyes in first row and two large eyes in each of the other rows (Fig. 17) ..... *Lycosidae*
16. Eyes in two rows (Fig. 18) ..... *Pisauridae*

17. Legs very long and slender; chelate chelicerae ..... *Pholcidae*
17. Legs of usual length; with uncate chelicerae 18

18. Hind spinnerets very long 19
18. Hind spinnerets of usual length 20

19. Six spinnerets nearly in a transverse row (Fig. 3) ..... *Hahniidae*
19. Six spinnerets clustered in the usual position. (Hind spinnerets may not be so greatly elongated in certain members of the family) ... *Agelenidae*

20. Eyes all dark, with anterior medians very small and a characteristic arrangement of all eyes with six large eyes forming a hexagon (Fig. 21) *Oxyopidae*
20. Eyes not grouped in a hexagon 21

21. External surface of chelicerae with stridulating ridges; lateral condyle of chelicerae absent; eyes heterogeneous; sheet-web weavers; mostly small spiders ..... *Linyphiidae*
21. External surface of chelicerae without stridulating ridges; lateral condyle of chelicerae usually present, but sometimes rudimentary or lacking (Fig. 2); eyes usually homogeneous; orb weavers; mostly large spiders ..... *Argiopidae*

Classification of the Spiders of Michigan

(Slightly modified from Petrunkevitch)

order araneae

I. Suborder Liphistiomorphae

Known from only a small portion of the eastern part of the Eastern Hemisphere.

II. Suborder Mygalomorphae

Not represented in Michigan.

III. Suborder Arachnomorphae

1. Branch Tetrasticta

1. Family Dysderidae.

No representatives of this family have been found in Michigan, but the family should occur here, and for that reason is included in my tables.

2. Branch Trionycha

2. Family Oecobiidae
3. Family Amaurobiidae
4. Family Agelenidae
5. Family Hahniidae
6. Family Pisauridae
7. Family Lycosidae
8. Family Oxyopidae
9. Family Sicariidae
10. Family Dictynidae
11. Family Theridiidae
12. Family Pholcidae
13. Family Linyphiidae
14. Family Uloboridae
15. Family Argiopidae
16. Family Mimetidae

3. Branch Dionycha

17. Family Drassidae
18. Family Thomisidae
19. Family Clubionidae
20. Family Anyphaenidae
21. Family Attidae

The Chief Diagnostic Characters of the Families of Michigan Spiders

DYSDERIDAE

The Dysderidae of our region may be characterized as follows: They are six-eyed spiders, with the anterior median eyes always missing. They have four spiracles, one pair of lung slits, and one pair of tracheal spiracles, which are placed just behind the epigastric furrow. All the coxae are long and cylindrical. There is no thoracic groove. The chelicerae lack the lateral condyle, but they have long, oblique grooves into which the fangs fit. The lip is free and long. The posterior coxae are widely separated by a prolonged sternum. The third pair of legs is often directed forward instead of backward in the usual manner. This is a small family, with but two species expected in Michigan. These spiders spin a primitive kind of web and probably make no true egg cocoons. The male palpus is simple.

OECOBIIDAE

This family is generally regarded as tropical and subtropical. It contains but one genus. The only specimen found in Michigan may have been a stray individual. The cephalothorax is broader than long, and the eyes are clustered near its middle. The eyes are heterogeneous. The chelicerae are small and lack the lateral condyle. The maxillary lobes are strongly convergent at the tips. The cribellum is narrow and delicately divided, and an inconspicuous calamistrum is present. The second segment of the posterior spinnerets is elongated

and provided with long spinning tubes on the inner side. The post-abdomen is prominent between the posterior spinnerets.

AMAUROBIIDAE

These spiders usually have been united with the Dictynidae but, in accord with Petrunkevitch's system, they are now regarded as constituting a distinct family. They possess a divided cribellum and a calamistrum on each posterior metatarsus. The thoracic groove is longitudinal. The chelicerae are prominent and provided with a lateral condyle, and both margins of the fang groove are toothed. There are three tarsal claws. The sternum is not prolonged between the posterior coxae. The eight eyes are in two rows, and only the anterior medians are dark. But one genus occurs in Michigan. Several species are common in stone walls and stumps, under bark, in hollow logs, and beneath overhanging banks and stones, where they spin loose, irregular webs with little definite plan.

AGELENIDAE

All our Michigan Agelenidae have eight eyes in two rows. The eyes are usually heterogeneous. There are three tarsal claws. The posterior spinnerets are usually very long, but this is not so noticeably true of some of the smaller members of the family. The cephalic and the thoracic portions of the cephalothorax are separated by shallow grooves. The chelicerae are often swollen in front at the base. These spiders spin sheet webs, often with a tubular retreat, hence the common name of funnel-web weavers. Some of our most common spiders, such as *Agelena naevia* Walckenaer, the grass spider, belong to this family.

HAHNIIDAE

Until recently this family has been regarded as a subfamily of the Agelenidae. At present, for a number of reasons, the best of which are derived from Petrunkevitch's recent studies (1933) of the internal anatomy of spiders, it is desirable to consider the group as a family. There is but a single genus in our region, and this can be placed easily by noting the six spinnerets arranged in a single transverse row, with the long posterior ones at the ends of the line. The posterior spiracle is prominently situated near the middle of the venter. These spiders spin sheet webs, which are small and usually located near the surface of the ground.

PISAURIDAE

These spiders are generally hairy and long-legged. They are often found around bodies of water and may be termed semiaquatic. All our Michigan Pisauridae have the eight eyes in two rows (Fig. 18), and they are all dark. There is a semicircular, bordered notch in the ventral side of the trochanters at the distal end. There are three tarsal claws. The males possess a spur or apophysis at the distal end of the tibia of the palpus. The integument is covered with plumose hair. All our Pisauridae hold the egg sacs with the chelicerae while carrying them. Because the females build special webs for the spiderlings this group is commonly known as nursery-web weavers.

LYCOSIDAE

These are the wolf spiders. The integument is covered with simple hair, and the legs are shorter than in the preceding family. The eight eyes, which are all dark, are arranged in three rows, as illustrated in Figure 17. The anterior row consists of four small eyes, but each of the other two rows is composed of two large eyes. The egg sac is attached to the spinnerets, and the spiderlings are carried on the backs of the mothers. The trochanters are deeply notched, as in the preceding family. The tibia of the male palpus is without an external apophysis. This is a large family and very common in Michigan.

OXYOPIDAE

These are the lynx spiders. They have long legs provided with long numerous spines. They run and jump freely over the vegetation in pursuit of their prey. They have three tarsal claws without a scopula. The trochanters are not notched except slightly in the posterior pair. There are eight dark eyes, and the anterior medians are very small, with the remaining six eyes forming a hexagon (Fig. 21). The integument is provided with scalelike hair. The abdomen tapers to a point at the posterior end. The family is poorly represented in Michigan.

SICARIIDAE

There are six eyes in all Michigan Sicariidae, and they are arranged in three groups of two each. All the eyes are nocturnal (pearly white). The labium and the sternum are not clearly separated by a distinct

suture. The lip is long, and the maxillary lobes are convergent. There are three tarsal claws, and the pedipalp of the female is without a claw. These spiders are mostly tropical and subtropical, with but one genus and one species occurring in Michigan. The male palpus is very simple.

DICTYNIDAE

These are small spiders generally found on the bark of trees, among flower heads, leaves of plants, and sometimes beneath stones and in forest débris. They are very well represented in Michigan. There are an undivided cribellum and a calamistrum on each posterior metatarsus. There are either six or eight eyes in two rows. The thoracic groove is longitudinal. Each chelicera has a lateral condyle. The maxillary lobes are convergent and possess scopulae. There are three tarsal claws.

THERIDIIDAE

The most distinctive character in these spiders is the comb on the ventral surface of the posterior tarsi; it is composed of a series of strong, curved, serrated setae (bristles) used for flinging silk over the entangled prey. Males frequently have stridulating organs on the abdomen and the cephalothorax. There is no lateral condyle on the chelicerae; the promargin is usually smooth, and the retromargin is always so. The legs are without true spines, and the tarsi have three claws. The eight eyes are arranged in two rows and are always heterogeneous. Their webs are irregularly built with threads extending in all directions, but there is often a tent or a retreat beneath which the spider hangs.

PHOLCIDAE

There are either eight or six eyes in these spiders; if there are eight eyes the two anterior medians only are diurnal. The two groups of three eyes on each side are always nocturnal. The chelicerae are chelate and without a lateral condyle. The pedipalps of the female are without claws. The tarsi are long and flexible and usually have false segmentation lines. There are serrated bristles on the tarsi, but no comb, as in the Theridiidae. All the whole legs are very much elongated, and there are three tarsal claws. The maxillary lobes are convergent and usually contiguous at the distal ends.

LINYPHIIDAE

These spiders frequently have been included as a part of the Theridiidae or the Argiopidae, but they are now generally separated from both families. Both species and individuals are numerous in Michigan. They build sheet webs and hence are commonly called sheet-web weavers. They have eight eyes, which are heterogeneous and variously arranged. There are three tarsal claws. The chelicerae have no lateral condyle, but more or less distinct organs of stridulation occur on the external surface of the basal segments of these organs and the fang margins are oblique and toothed. The legs are either smooth or provided with fine spines.

ULOBORIDAE

This is a small family consisting of only two genera in this region. They possess a cribellum, which is undivided, and a calamistrum on the posterior metatarsi. There are eight eyes, which occur in two rows, and they are all dark. There are three tarsal claws. One member of this family in Michigan spins an orb web like those of the Argiopidae.

ARGIOPIDAE

These are the true orb weavers and are the best known of all groups of spiders. The family is very well represented in Michigan. There are eight eyes, usually homogeneous. There are three tarsal claws. The lateral condyle of the chelicerae is usually present, but it is sometimes lacking or rudimentary. The margins of the fang groove are oblique and toothed, and there are no stridulating ridges such as occur in the Linyphiidae. The legs are usually provided with stout spines.

MIMETIDAE

This is another family which is poorly represented in Michigan; there are but two genera and two species. They are easily distinguished by the armature which occurs on the prolateral surfaces of the first two pairs of tibiae and metatarsi. The tarsi have the serrated bristles, but not a comb such as occurs in the Theridiidae. The chelicerae are without a lateral condyle, but both margins are toothed. The maxillary lobes are convergent. The eight heterogeneous eyes are in two rows, and the lateral eyes are contiguous. These spiders probably make no definite webs.

DRASSIDAE

This family is also well represented in Michigan. The cephalothorax is low, and the body is usually smooth or covered with short hair. They occur mostly beneath stones and bark, in moss, in rolled leaves, etc. They do not spin webs. There are two tarsal claws and tarsal pads or scopulae. The anterior spinnerets are widely separated and stoutly cylindrical. The posterior coxae are separated by the sternum. The maxillary lobes are convergent and usually transversely depressed. The chelicerae have lateral condyles and toothed fang margins. The thoracic groove is always longitudinal. There are always eight eyes in all Michigan Drassidae, arranged in two rows of four each, with only the anterior median eyes dark.

THOMISIDAE

The members of this family are known as crab spiders because they are laterigrade. The body is usually short and broad (Tibellus is a noteworthy exception). The tarsal claw tufts are usually present, but are sometimes lacking. There are eight eyes, arranged in two rows of four each, and they are all dark. The lower margin of the fang groove of the chelicerae is indistinct and unarmed; the upper margin has one or two teeth. The pedipalp of the female has a claw. These spiders spin no webs.

CLUBIONIDAE

No true webs are spun by the Clubionidae, but they frequently construct nests and retreats by fastening leaves together with silken threads. There are eight eyes in two rows of four each. There are only two tarsal claws, but there is a claw tuft usually present. The lower margin of the fang groove is distinct and armed with teeth. The fore spinnerets are contiguous.

ANYPHAENIDAE

The habits of these spiders are similar to those of the preceding family. Until recently the Anyphaenidae have been included in the same family with the Clubionidae. Most of the differences that separate the two families are obscure and difficult to deal with in an elementary way. The position of the tracheal spiracle near the middle of the abdomen separates them from the preceding family. There is a single genus in the state, with several species.

ATTIDAE

This is a very large family and is well represented in Michigan. They are the well-known jumping spiders. They make no true webs, but spin nests which are always saclike and serve as retreats. The eight eyes are in three rows, as shown in Figure 19. All eyes are diurnal (dark). The chelicerae lack the lateral condyle. The pedipalp of the female is without a claw. There are two tarsal claws, accompanied by a prominent claw tuft. The legs are adapted for jumping and are usually short and stout. The body is also short and stout in most species, and it is usually covered with hair or scales, which are often brilliantly colored and iridescent.

GLOSSARY

Anterior spiracle. — *See* Spiracles.

Apophysis. — A strongly chitinized outgrowth of a segment of the pedipalp or of some other appendage.

Calamistrum. — One or two rows of curved, stiff hairs on the dorsal surface of the posterior metatarsi of certain spiders, used in combing out the broad band of silk produced by the cribellum.

Chelate chelicerae. — *See* Chelicerae.

Chelicerae. — The first pair of appendages borne by the cephalothorax situated in front of the mouth, regarded as modified antennae homologous to the second antennae of Crustacea. Each chelicera consists of a large basal segment and a smaller terminal one, which is called the fang. These organs are used to seize and kill prey. When it is closed against the basal segment the fang usually fits into a groove called the fang groove. Many chelicerae have on the dorsolateral face of the basal segment a distinct articular protuberance called the lateral condyle or boss. In a few spiders an outgrowth from the basal segment meets the tip of the fang to produce the chelate type of chelicera. When this outgrowth does not occur the chelicera is of the uncate type.

Comb. — A series of serrated, curved setae on the fourth tarsi of Theridiidae (Fig. 8). Used to fling silk over the entangled prey.

Claws. — *See* Tarsal claws.

Cribellum. — An organ of sievelike appearance with many spinning tubes situated just in front of the true spinnerets, usually regarded as the source of the hackled band of certain kinds of webs. It is considered a modification of a pair of spinnerets.

Eyes. — The eyes of all spiders are simple and somewhat resemble the ocelli of insects. Certain of these eyes are pearly white and are called nocturnal eyes, while others lack the pearly lustre and are called diurnal eyes. The terms "nocturnal" and "diurnal" now seem to be of doubtful propriety. Spiders may have all of one type, when they are said to have homogeneous eyes, or they may have both types and are then said to have heterogeneous eyes.

Fang groove. — *See* Chelicerae.

Hairs. — Products of certain hypodermal cells that give the hairy appearance of

these animals. The hairs may be simple shafts or plumose or scalelike in form.

Labium. — An appendage just in front of the sternum, lying between the maxillary lobes of the pedipalps.

Lateral condyles. — *See* Chelicerae.

Laterigrade. — *See* Prograde.

Lip. — *See* Labium.

Lung slits. — *See* Spiracles.

Maxillary lobes. — The coxa of each pedipalp bears a plate (Fig. 1), called a maxillary lobe, which is used for crushing the prey and squeezing the juices from it.

Pedipalps. — The second of the two pairs of appendages borne by the head or cephalic part of the cephalothorax. In adult males the tarsus is modified into a remarkable copulatory organ.

Prograde. — Used to indicate the usual manner of walking or running. Crab spiders and certain other groups walk sidewise and are said to be laterigrade.

Prolateral Surface. — In accordance with the terminology used by Petrunkevitch (1925), the appendages are thought of as extending outward at right angles to the body. Then the prolateral surface is the anterior surface, while the retrolateral surface is the posterior surface of all appendages. The ambiguous terms "inner" and "outer," which differ with different appendages, are thus avoided.

Promargin. — A term applied to the upper or outer margin of the chelicera of true spiders, while the lower or inner margin is named the retromargin.

Scopula. — A brush of hairs on the maxillary lobes is called a maxillary scopula. A similar brush of hairs may occur on the chelicerae. In many spiders pads or brushes of specialized hairs occur on the metatarsi and the tarsi. These are also often called scopulae.

Spinnerets. — The elongated tubes usually situated near the posterior end of the ventral side of the abdomen just in front of the anal tubercle.

Spiracles. — Openings of the respiratory organs on the ventral surface of the abdomen. The anterior spiracles, usually one pair but sometimes two pairs, called "lung slits," lead to the book lungs near the anterior end of the abdomen close to the epigastric furrow (Fig. 1). The posterior spiracle or tracheal spiracle usually lies just anterior to the spinnerets, but sometimes near the middle of the abdominal surface. Ordinarily a single opening leads to tracheal tubes, which ramify among the internal organs more or less completely, but in the Dysderidae two openings occur (Fig. 4).

Stridulating ridges. — Ridges on the external surface of the basal segments of the chelicerae, over which the prolateral surface of the femur of the pedipalps is drawn to produce sound.

Tarsal claws. — Claws which occur at the distal end of each tarsus of each leg. There may be two or three claws. In the former case the claws may or may not be accompanied by a pad of specialized hairs (Figs. 5, 7).

Thoracic groove. — A groove in the thoracic portion of the carapace (Fig. 2).

Tracheal spiracle. — *See* Spiracles.

Uncate chelicerae. — *See* Chelicerae.

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LITERATURE CITED

Chickering, Arthur M. 1932. Notes and Studies on Arachnida. II. Araneae from the Douglas Lake Region, Michigan. I. Pap. Mich. Acad. Sci., Arts and Letters, 15 (1931) : 349–355.

—— 1933. Notes and Studies on Arachnida. IV. Araneae from the Douglas Lake Region, Michigan. II. *Ibid.*, 17 (1932) : 515–520.

—— 1934. Araneae from the Northern Peninsula of Michigan. *Ibid.*, 19 (1933) : 577–580.

—— 1935. Further Additions to the List of Araneae from Michigan. *Ibid.*, 20 (1934) : 583–587.

—— 1933. Opportunities for Teachers in the Study of the Natural History of Spiders. Chapter XIV of "Opportunity for Investigation in Natural History by High-School Teachers." Journal of the Michigan Schoolmasters Club, 35 (1) : 84–89 (repaged in reprints).

—— and Bacorn, Gertrude. 1933. Notes and Studies on Arachnida. V. Additions to the List of Araneae from Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 17 (1932) : 521–528.

Petrunkevitch, A. 1925. Arachnida from Panama. Trans. Conn. Acad. Arts and Sciences, 27 : 51–248.

—— 1928. Systema Aranearum. *Ibid.*, 29 : 1–270.

—— 1933. An Inquiry into the Natural Classification of Spiders, Based on a Study of Their Internal Anatomy. *Ibid.*, 31 : 299–389.

EXPLANATION OF PLATE LVIII

EXTERNAL ANATOMY OF THE SPIDER

Fig. 1. Ventral surface of a spider. A, tracheal spiracle; B, spinnerets; C, epigastric furrow; D, anterior spiracle; E, epigynum; F, labium; G, basal segment of chelicera; H, fang; I, pedipalp; J, maxillary scopula; K, maxillary lobe; L, sternum; T, coxa; M, trochanter; N, femur; O, patella; P, tibia; R, metatarsus; S, tarsus

Fig. 2. Dorsal surface of the cephalothorax of a spider. U, thoracic groove; V, cephalic groove; W, lateral condyle or boss; X, basal segment of chelicera

Fig. 3. Ventral surface of the abdomen in the Hahniidae

Fig. 4. Ventral surface of the abdomen in the Dysderidae, showing the two tracheal spiracles

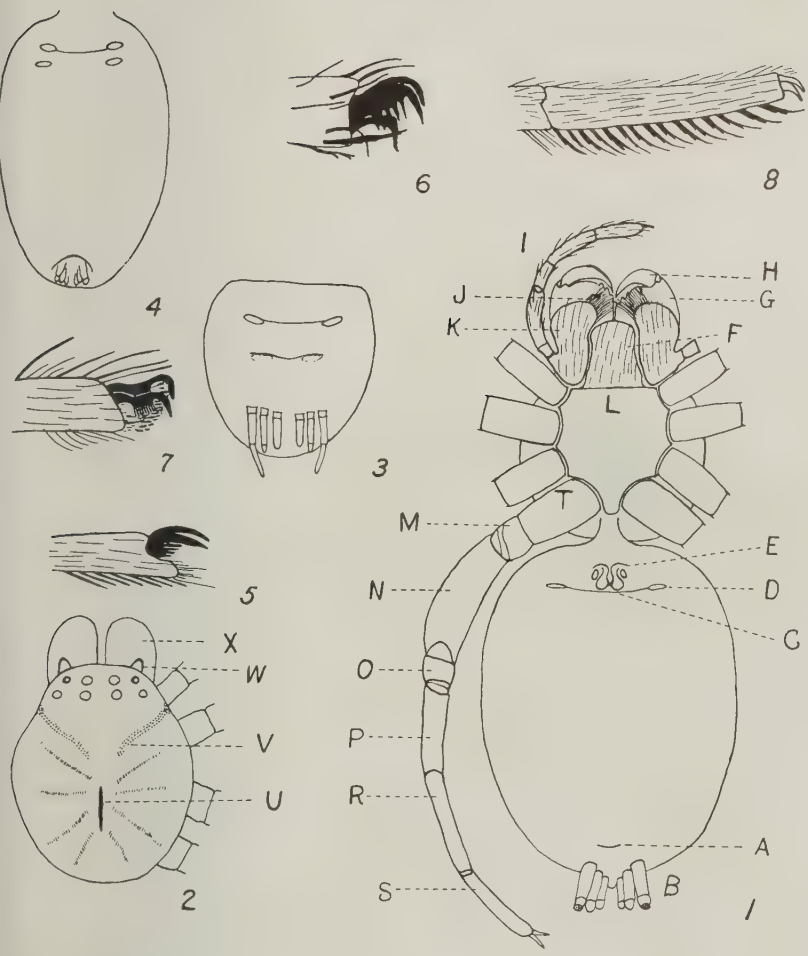
Fig. 5. Tarsus with two claws without tarsal pad

Fig. 6. Tarsus with three claws

Fig. 7. Tarsus with two claws and tarsal pad

Fig. 8. Fourth tarsus in the Theridiidae, showing the "comb"

PLATE LVIII



EXPLANATION OF PLATE LIX

EXTERNAL ANATOMY OF THE SPIDER

FIG. 9. An uncate chelicera

FIG. 10. A chelate chelicera

FIG. 11. Stridulating ridges on external surface of a chelicera

FIG. 12. The bordered notch in a trochanter

FIG. 13. Amaurobiid type of cribellum

FIG. 14. The same type on a small scale, showing position just anterior to the spinnerets

FIG. 15. Fourth metatarsus, with its calamistrum

FIG. 16. Armature of the mimetid tibia and metatarsus

FIG. 17. Eye group of the Lycosidae

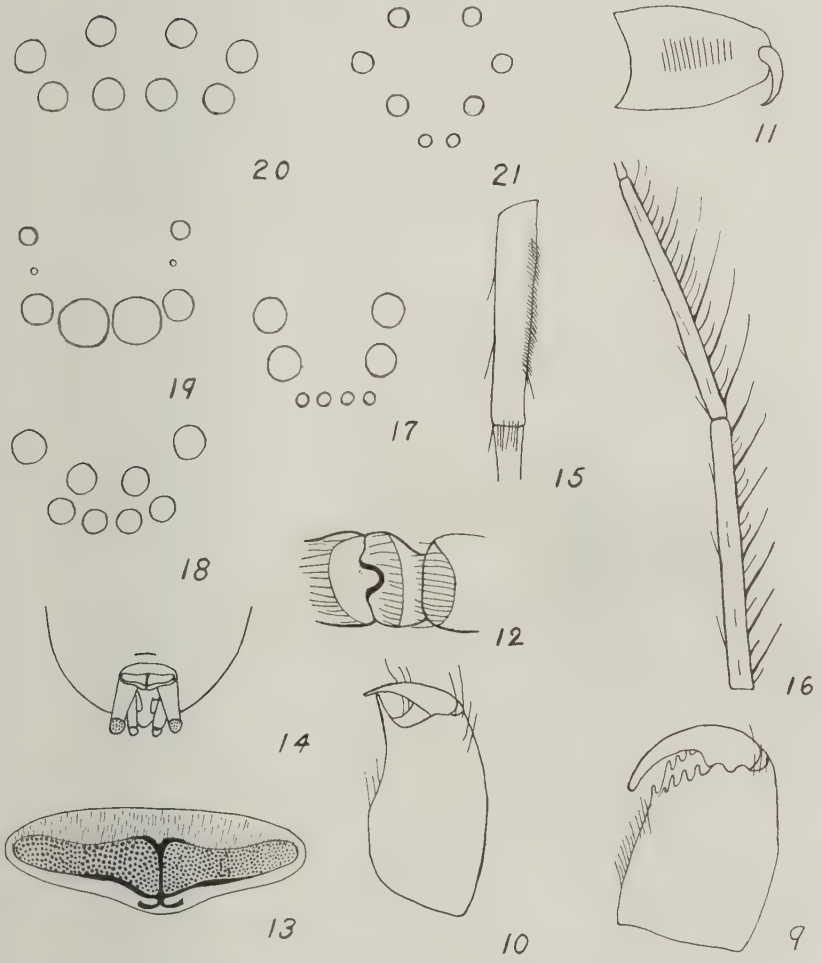
FIG. 18. Eye group of the Pisauridae

FIG. 19. Eye group of the Attidae

FIG. 20. Eye group of the Clubionidae

FIG. 21. Eye group of the Oxyopidae

PLATE LIX



AGE AND GROWTH OF THE GOLDEN SHINER (*NOTEMIGONUS CRYSOLEUCAS AURATUS*) AND ITS SUITABILITY FOR PROPAGATION *

GERALD P. COOPER

STUDIES on the rate of growth of the golden shiner (*Notemigonus crysoleucas auratus*) were made by the scale method on 1,058 specimens from twenty Michigan localities. Details concerning these various collections, together with the tabulation of the average standard lengths of the age groups of each, are presented in Table I. There occurs a marked variation in rate of growth within the state. There is a correlation between the rate of growth of the golden shiners and two climatic gradients indicated by Seeley (1922), namely: (1) the average number of days in the growing season (from the last killing frost in spring to the first killing frost in autumn), and (2) the mean annual air temperature. These fish grow more rapidly in the warmer waters of southern Michigan than they do in the colder waters in the northern part of the state (Table I and Fig. 27). This correlation between rate of growth and certain climatic features is in accordance with the results presented by Hubbs and Cooper (1935) for the long-eared sunfish (*Xenotis megalotis peltastes*) and the green sunfish (*Apomotis cyanellus*) in Michigan.

The specimens considered in this study were collected chiefly by two types of gear: gill nets (of various sizes of mesh) and seines (common-sense and coarse meshes). Gill nets took chiefly those collections containing only large specimens (for example, all the collections from lakes in Kalkaska County and those from Nichols and Eagle lakes). The collections containing large numbers of small fish (for example, those from Watkins Lake and Huron and Manistee rivers) were made with seines. Thus in individual collections, owing to the type of gear used, there was considerable selectivity for certain sizes

* Contribution from the Institute for Fisheries Research, University of Michigan.

of specimens. The unnatural size distribution of the specimens from different localities is somewhat compensated for by combining the collections. A cross section of the natural population, fairly representative in size distribution, is obtained by combining the results

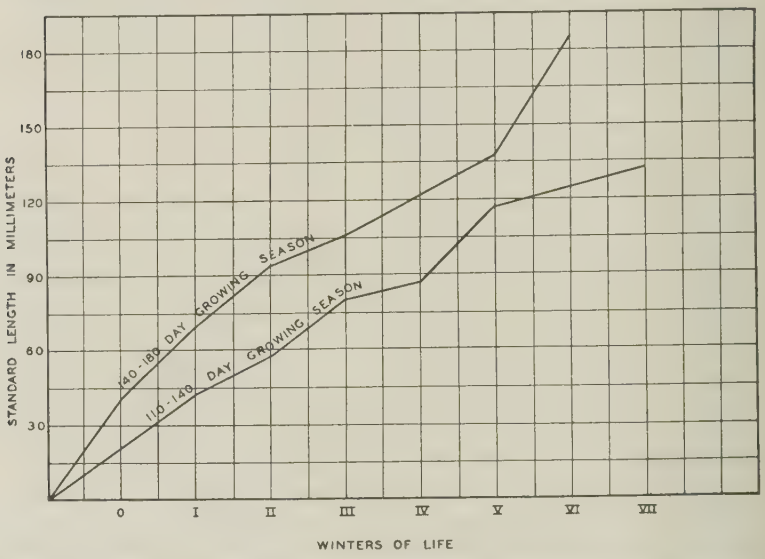


Fig. 27. Rate of growth of golden shiners from Michigan localities correlated with the average number of days in the growing season (from the last killing frost in spring to the first killing frost in autumn). The Roman numerals refer to completed winters of life. Data are from Table I

of the age and growth studies made upon the specimens from all localities.

The Huron River series collected on May 19, 1934, by the writer, with the aid of Dr. Henry Vander Schalie, proved especially adequate for studies on rate of growth in that it contained a large number of specimens having a wide range in size. At the time the collection was obtained there was a great concentration of these minnows just below the power dam at Ypsilanti. One haul with a 25-foot common-sense seine yielded 541 specimens of golden shiners, together with several hundred sunfish, crappies, carp, and other species. Since the entire lot was preserved, the group of shiners used in this study represents a random sample of this crowded population.

TABLE I

RATE OF GROWTH OF GOLDEN SHINERS FROM MICHIGAN LOCALITIES

The collections are grouped according to the length of growing season and to the mean annual temperature. The average standard length in millimeters for each age group is given for each locality. The inferior number appended to each average is the number of specimens upon which the average is based.

Growing season; mean temp. County Lake or stream; date	Winter marks							
	0	I	II	III	IV	V	VI	VII
110–140 days; 39°–45° F.								
Luce Co.								
Killhain L., 6/23	....	32.3_{7}	53.8_{11}	61.5_{34}	65.8_{9}	....	....	....
Kalkaska Co.								
Bass L., 9/4	....	....	....	....	101.0_{1}	125.3_{4}	....	....
Bass L., 7/27	....	....	....	....	116.0_{1}	126.0_{1}	123.5_{2}	....
East L., 9/1	....	....	....	107.0_{2}	....	120.5_{4}	125.5_{2}	133.5_{2}
Indian L., 7/13	....	....	88.0_{1}	110.1_{12}	122.5_{2}	120.0_{1}	....	....
Perch L., 7/5	....	....	....	105.7_{6}	107.6_{5}	116.0_{1}	....	....
Manistee Co.								
Manistee R., 4/14	....	34.4_{26}	54.3_{40}	65.3_{7}	75.2_{6}	93.5_{2}	....	....
Iosco Co.								
Cooks Dam, 6/11	....	....	....	98.0_{10}	102.0_{4}	113.3_{3}	....	....
Alcona Co.								
Alcona Dam, 6/6, 7	....	57.2_{4}	70.3_{9}	82.9_{8}	90.0_{2}	....	....	....
Gladwin Co.								
Ross L., 6/26	....	48.1_{49}	69.5_{4}	....	....	....	....	....
140–180 days; 45°–50° F.								
Newaygo Co.								
Nichols L., 9/16	....	....	....	121.1_{8}	....	....	....	....
Ingham Co.								
Jones L., 6/24	....	....	....	114.0_{1}	....	131.0_{1}	....	....
Kent Co.								
Hatchery; spring	....	....	....	....	....	....	192.0_{1}	....
Jackson Co.								
Watkins L., 9/29	41.1_{48}	69.4_{62}	95.0_{10}	111.0_{1}	....	....	....	....
Washtenaw Co.								
Third Sister L., 6/21	....	55.3_{3}	....	129.3_{3}	133.7_{3}	....	....	....
Huron R., 5/8	....	56.3_{79}	101.7_{3}	....	....	....	....	....
Huron R., 5/19	....	71.0_{302}	91.6_{170}	101.9_{53}	115.7_{14}	126.5_{2}	....	....
Wayne Co.								
Edison L., 6/24	....	....	121.2_{6}	117.0_{1}	....	....	....	....
Van Buren Co.								
Eagle L., 5/14	....	....	....	....	....	....	183.0_{1}	....
Lenawee Co.								
Dewey L., 4/29	....	....	....	....	172.0_{1}	170.0_{2}	177.0_{1}	....
110–140 days; 39°–45° F. Summary	....	43.1_{86}	57.9_{65}	80.5_{79}	87.7_{30}	117.0_{16}	124.5_{4}	133.5_{2}
140–180 days; 45°–50° F. Summary	41.1_{48}	68.1_{446}	92.9_{189}	105.9_{67}	121.8_{13}	137.0_{5}	184.0_{3}	....
All localities Grand summary	41.1_{48}	64.0_{532}	83.9_{254}	92.2_{146}	100.5_{48}	121.8_{21}	150.0_{7}	133.5_{2}

TABLE II

SIZE FREQUENCIES FOR EACH AGE GROUP OF GOLDEN SHINERS TAKEN FROM THE HURON RIVER AT YPSILANTI ON MAY 19, 1934

Standard length in mm.	Winter marks									
	I		II		III		IV		V	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
46– 48	..	2	..	..	..	..	..	..	..	..
49– 51	1	..	..	..	..	..	..	..	..	..
52– 54	1	1	..	..	..	..	..	..	..	..
55– 57	..	5	..	..	..	..	..	..	..	..
58– 60	8	7	..	..	..	..	..	..	..	..
61– 63	20	11	..	..	..	..	..	..	..	..
64– 66	17	16	..	..	..	..	..	..	..	..
67– 69	27	15	..	..	..	..	..	..	..	..
70– 72	21	18	..	..	..	..	..	..	..	..
73– 75	28	10	..	..	..	..	..	..	..	..
76– 78	24	15	2	..	..	..	..	..	..	..
79– 81	18	15	3	..	..	..	..	..	..	..
82– 84	6	7	9	4	..	..	1	..	..	..
85– 87	3	4	11	10	2	..	..	..	..	..
88– 90	1	1	23	14	3	1	..	..	..	..
91– 93	..	..	21	16	4	1	..	..	..	..
94– 96	..	..	12	17	1	6	..	..	..	..
97– 99	..	..	2	9	1	3	..	..	..	..
100–102	..	..	2	10	1	3	..	..	..	..
103–105	..	..	1	1	1	6	1	..	..	..
106–108	..	..	..	1	1	6	..	1	..	..
109–111	..	..	..	..	1	5	1	2	..	..
112–114	..	..	..	..	..	3	1	1	..	..
115–117	..	..	1	1	1	2	..	..	..	..
118–120	..	..	..	..	..	1	..	1	..	..
121–123	..	..	..	..	..	..	..	2	..	1
124–126	..	..	..	..	..	..	..	..	..	..
127–129	..	..	..	..	..	..	..	..	..	..
130–132	..	..	..	..	..	..	..	1	..	1
133–135	..	..	..	..	..	..	..	1	..	..
136–138	..	..	..	..	..	..	..	..	..	..
139–141	..	..	..	..	..	..	..	..	..	..
142–144	..	..	..	..	..	..	..	1	..	..
Average length in mm.*....	71.2	70.7	89.9	93.4	96.3	104.3	102.8	120.8	..	126.5
No. specimens.	175	127	87	83	16	37	4	10	..	2

* The average lengths were calculated from the frequencies for each millimeter size group, not from the frequency classes given in this table.

The rate of growth of the specimens in this Huron River series is summarized in Table II and Figures 28-29. The scales of only two specimens of the series (one each of the I- and II-year groups) show growth in the 1934 growing season. Although the 1934 winter annulus had not been formed on the scales of any except these two specimens, the margin of the scale is considered to represent an annulus. Therefore "winter marks" (as used in Table II) refers to completed winters of life; for example, the I-group are young of the previous summer; and the II-group are young of 1932. The designated average length of each year class is the actual size attained at the end of each growing season. Compared with the same species in other localities, the young golden shiners of this series had an excellent growth during the summer of 1933. Their better growth is more pronounced than is indicated by Table I, since these young had no growth in their second summer, whereas the young in most of the other collections had made part of their second summer's growth by the time they were collected. Diameters of scale areas representing periods of growth indicated that the two-year-old fish had attained a large size in 1933, but that their growth as young in 1932 was much less than that of the young of 1933. This seems to indicate that for this species conditions in the Huron River were better during the summer of 1933 than during 1932.

Maturity appears to be related to the size at the end of the first year, that is, in any one locality maturity is determined by size rather than by age.[1] The larger young are the first to reach maturity, at which time there is a noticeable slackening in rate of growth. In the large Huron River series growth areas on scales of the two-year-old specimens indicated that the shiners which had attained a large size in their first year and which apparently had reached maturity early in their second summer grew little during their second year. Conversely, those shiners which grew little in their first summer (as was true of most of the II-year class) were apparently immature through most, if not all, of their second summer, during which they made a rapid growth. This species therefore appears to show the phenomenon of growth compensation.

In the Huron River series all the one-year-old females, except a

[1] This, however, does not appear to be of universal application to the species. Hubbs (1921) mentioned that most of the greatly dwarfed golden shiners of San Diego River, California, become mature at the end of their first year of life.

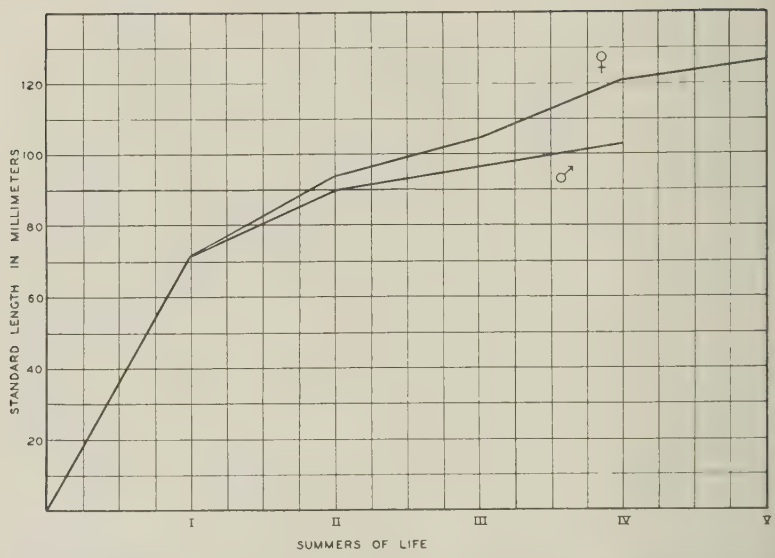


FIG. 28. Rate of growth of the two sexes of golden shiners collected from the Huron River on May 19, 1934. Data are from Table II

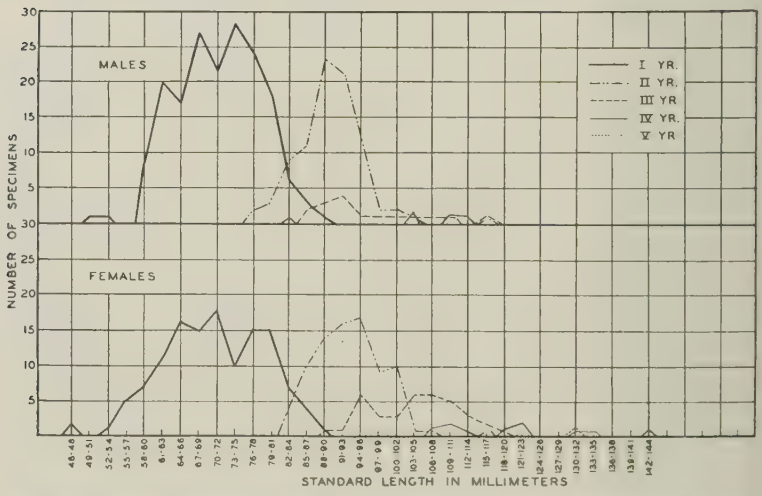


FIG. 29. Length-frequency distribution of each age group of the two sexes of golden shiners from the Huron River, May 19, 1934. Data are from Table II

TABLE III

AVERAGE STANDARD LENGTHS IN MILLIMETERS OF THE TWO SEXES OF GOLDEN SHINERS IN THOSE AGE GROUPS CONTAINING BOTH SEXES

The inferior number appended to each average is the number of specimens upon which the average is based.

Locality	Date	Winters of life									
		I		II		III		IV		V	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Killhain L.	6/23	41.5_{2}	29.7_{3}	54.0_{9}	53.0_{2}	57.0_{1}	61.6_{33}	...	...	...	...
Manistee R.	4/14	...	...	55.3_{21}	53.2_{19}	68.0_{2}	64.2_{5}	...	...	...	...
Alcona Dam	6/6, 7	57.3_{3}	57.0_{1}	68.5_{2}	70.8_{7}	...	...	...	...	...	...
Ross L.	6/26	47.2_{24}	49.0_{25}	68.0_{1}	70.0_{3}	...	...	...	...	...	...
Nichols L.	9/16	...	...	...	...	125.8_{4}	116.3_{4}	...	...	...	...
Jones L.	6/24	...	...	...	...	...	...	...	...	135.0_{1}	127.0_{1}
Watkins L.	9/29	69.1_{33}	69.7_{29}	96.8_{5}	93.2_{5}	...	...	...	...	...	...
Third Sister L.	6/21	...	...	...	...	123.0_{1}	132.5_{2}	124.0_{1}	138.5_{2}	...	...
Huron R.	5/8	56.2_{28}	56.4_{51}	...	...	...	...	...	...	...	...
Huron R.	5/19	71.2_{175}	70.7_{127}	89.9_{87}	93.4_{83}	96.3_{16}	104.3_{37}	102.8_{4}	120.8_{10}	...	...
Edison L.	6/24	...	...	116.0_{2}	123.8_{4}	...	...	...	...	...	...

few of the smallest, and all females of subsequent year groups were mature and would have spawned during the 1934 season. The ova in all maturing females were of approximately the same size (about 0.5 mm. in diameter). The principal difference between the various age groups of females was in the size of the ovaries and the number of eggs which they contained rather than in the size of the eggs — the ovaries of the older fish were larger and contained more eggs. Observations on the testes indicated that the males were maturing at the same age as the females.

In general, the age of maturity of golden shiners in all the warmer waters of the southern part of the state agrees with that of the 1933 young of the Huron River series — the second summer of life. In the colder waters of the northern part of the state maturity is usually delayed until the third summer. The approximate size at which maturity is reached is 50 to 70 millimeters standard length, or $2\frac{1}{2}$ to $3\frac{1}{2}$ inches in total length.

Sexual dimorphism in rate of growth is probably characteristic of this species; females grow more rapidly than the males (see Tables II–III and Figs. 28–29). Most of the collections contain too few specimens to demonstrate dimorphic growth; however, the largest and most reliable series (the Huron River collection of May 19) shows this phenomenon clearly. Since this difference in rate of growth first manifests itself in the second year of life, coincidentally with the first year of maturity, it is probable that these two phenomena are related.

Female golden shiners are distinctly more viable than males (see Table IV). The rapid change in the relative abundance of the two sexes, with increase in age, is not due to greater ease in catching spawning females as compared with males. The two sexes are represented in equal numbers in the II-group (third summer), at which age practically all females are mature. A sudden drop in the number of males occurs after the third summer, and males older than four summers (three winters) are rare.

In the light of present knowledge golden shiners are well suited for propagation in ponds to furnish forage fish at hatcheries and to provide bait minnows. An unfavorable aspect of the western form from this point of view is that by the end of its first year of life it seldom reaches a sufficient size (four inches or more) for bass and pike bait. Therefore the slow growth would necessitate holding these

TABLE IV

THE NUMBERS OF EACH SEX OF GOLDEN SHINERS IN EACH AGE GROUP FROM ALL MICHIGAN LOCALITIES

	Winters of life						
	I	II	III	IV	V	VI	VII
Males.....	265	127	24	6	1	..	..
Females.....	239	127	121	42	21	6	2

shiners in ponds over winter in order that they might attain this desired size in the second summer; in northern Michigan it might be necessary to hold some fish until the third summer. More rapid growth can probably be induced by bettered environmental conditions or by selective breeding.

Studies on rate of growth were made on four collections of the eastern subspecies of the golden shiner (*Notemigonus crysoleucas crysoleucas*) to determine whether the eastern form is appreciably faster-growing, and hence a better forage and bait minnow than the western subspecies *auratus*. The dates and the localities of these New York collections[2] and the average standard length in millimeters of each age group within each collection are presented in Table V. The collection from Cooper's Pond was made with a 100-foot seine; the collection from Bachus Pond, with a short seine and a gill net; and the collections from Knickerbocker and Snyder lakes were made with gill nets. Because of the size selectivity of the methods of collecting and because of the small number of specimens in the collections, no extensive generalizations on the life history of the eastern subspecies can be made at this time. These data are given solely to show the general trend in rate of growth.

On the basis of the data presented a summary of the growth of these two subspecies is given at the end of Table V. These data indicate that the two forms grow at approximately the same rate for the first four summers. There is an indication that in the latter years of life the growth of the eastern subspecies (*crysoleucas*) is somewhat faster than that of the western subspecies (*auratus*); this difference might, however, be the result of gear selectivity in collecting

[2] Obtained through the courtesy of the New York State Biological Survey.

TABLE V

GROWTH OF THE EASTERN FORM OF THE GOLDEN SHINER (*NOTEMIGONUS CRYSOLEUCAS CRYSOLEUCAS*)

The four localities listed in this table are in the Hudson River drainage basin in New York State. The New York specimens were obtained during 1934. The average standard length in millimeters is given for each sex in each age group for the localities. At the bottom of the table a summary of the New York localities (eastern subspecies *crysoleucas*) and the Michigan localities (western subspecies *auratus*) is given for each age group.

County Pond or lake; date	Winters of life															
	0	I		II		III		IV		V		VI		VII		IX	
	♂ + ♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Columbia Co.																	
Bachus Pond, 8/6	38.5	..	..	..	..	..	149.0	..	..	..	168.4	140.0	187.0	..	..	207.0	..
No. of specimens	24	..	..	..	..	..	1	..	..	..	5	1	1	..	..	1	..
Knickerbocker L., 9/10	..	..	..	..	..	..	..	..	..	168.8	171.0	..	..	..	..	..	..
No. of specimens	..	..	..	..	..	..	..	..	..	4	4	..	..	..	..	..	..
Rensselaer Co.																	
Cooper's Pond, 9/9	..	73.0	..	85.0	..	83.0	92.1	..	..	..	..	..	..	..	..	..	..
No. of specimens	..	1	..	2	..	6	12	..	..	..	..	..	..	..	..	..	..
Snyders L., 8/28	..	..	..	..	..	151.0	..	..	..	166.0	167.4	..	169.0	..	..	..	..
No. of specimens	..	..	..	..	..	1	..	..	..	4	7	..	1	..	..	..	..
All New York localities	38.5	73.0	..	85.0	..	92.7	96.5	..	..	167.4	168.6	140.0	178.0	..	..	207.0	..
No. of specimens	24	1	..	2	..	7	13	..	..	8	16	1	2	..	..	1	..
	♂ + ♀	♂ + ♀		♂ + ♀		♂ + ♀		♂ + ♀		♂ + ♀		♂ + ♀		♂ + ♀		♂ + ♀	
All New York localities	38.5	73.0		85.0		95.2		....		168.2		165.3		....		207.0	
No. of specimens	24	1		2		20		....		24		3		....		1	
All Michigan localities	41.1	64.0		83.9		92.2		100.5		121.8		150.0		133.5		....	
No. of specimens	48	532		254		146		48		21		7		2		....	

the specimens. If the difference is real, one of the chief advantages of the eastern over the western form, as a forage minnow, would be that larger breeders could be used. Since the eastern subspecies is markedly a heavier-bodied fish, it might be expected to give in pond culture a greater production in weight than does the western subspecies.

University of Michigan

LITERATURE CITED

Hubbs, Carl L. 1921. Geographical Variation of Notemigonus crysoleucas — an American Minnow. Trans. Ill. State Acad. Sci., 11 (1918) : 147–151.

—— and Cooper, Gerald P. 1935. Age and Growth of the Long-eared and the Green Sunfishes in Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 20 (1934) : 669–696.

Seeley, Dewey A. 1922. Michigan Agriculture. 3. Climate, pp. 1–46, charts 1-16.

THE DEEP-WATER BOTTOM FAUNA OF LAKE MICHIGAN *

FRANK E. EGGLETON

Introduction

IT IS a challenging fact that our knowledge concerning the biology of those unique fresh-water seas, the five Great Lakes of North America, is still most aptly characterized by its paucity. The limnology of the Great Lakes has hardly been touched. The field dealing with the biology of their bottom fauna is practically virgin territory. The writer, therefore, gratefully accepted the opportunity presented when Dr. John Van Oosten, aquatic biologist in charge of Great Lakes Fisheries Investigations of the United States Bureau of Fisheries, offered to have a series of bottom-fauna samples taken from the deeper water of Lake Michigan and asked if the writer would study them.

Methods and Equipment

One series was taken throughout the spring, summer, and autumn of 1931; another during the 1932 season. Field work was done aboard the United States Bureau of Fisheries' motor ship *Fulmar*, a converted schooner of slightly more than one hundred feet in length. A few samples, principally for use as a check, were taken with an Ekman-Birge dredge measuring 22.5 by 22.5 centimeters. Nearly all the samples, however, were collected with a Petersen dredge, which weighed about 22.5 kilograms (50 pounds) and which covered a surface area of 625 square centimeters. The dredge was lowered and hauled in by a small winch, a steel cable, and a davit. At the outer end of the davit the cable passed over a meter wheel which registered directly the depth where the sample was taken (Pl. LX, Figs. 1–2).

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The contents of the dredge were emptied into a tub, in which they were mixed by the hands with strained surface water and poured into a cloth net, the straining surface of which was composed of fine-mesh grit gauze. In this the coarse débris and the captured animals were washed free from fine mud and sand. The residue in the net, both coarse débris and animals, was emptied into pint jars or bottles containing date–locality labels and preserved for later study (Pl. LXI).

The laboratory study of this material has been a time-consuming process, requiring for any reasonable degree of accuracy a slow, persistent searching and repeated reëxamination of very small portions of the débris. The following procedure was adopted at the outset and has been uniformly adhered to throughout that part of the work which has been completed. A small portion of the contents of a jar was emptied into an ordinary wire-mesh tea strainer, which had been lined with number 10 silk bolting cloth, and was there gently washed free of all remaining silt and "dust-fine detritus." Approximately 5 cubic centimeters of this washed material was then transferred to a flat glass dish 4 centimeters deep and 23 centimeters in diameter and floated out evenly over the bottom by filling about one third of the dish with water. The various macroscopic animals could then be removed by the use of pipettes, fine-pointed forceps, or metal seekers with fine, recurved points. As the animals were removed from the débris they were sorted into serially numbered vials, which were then plugged with cotton, packed in fruit jars, and covered with 70 per cent alcohol. After the larger animals had been removed, the débris was systematically searched under a binocular microscope for smaller organisms, eggs, embryos, cocoons, and the like. When the whole bottom of the dish had been searched in this way, the material was thoroughly mixed and redistributed over the bottom and reëxamined in the same manner. Sometimes it was necessary to mix the débris and to repeat the search several times before it was no longer possible to find a few, scattered small organisms or their various life-history stages. The microscope used for this work has been a Spencer Convertible Binocular, No. 58, equipped with removable stage and a large board covering the base of the instrument, on which the glass dish could be placed for examination. After the animals had all been removed from a sample they were placed in watch glasses, identified, enumerated under the binocular, and returned to the proper vials and jars for storage.

Acknowledgments

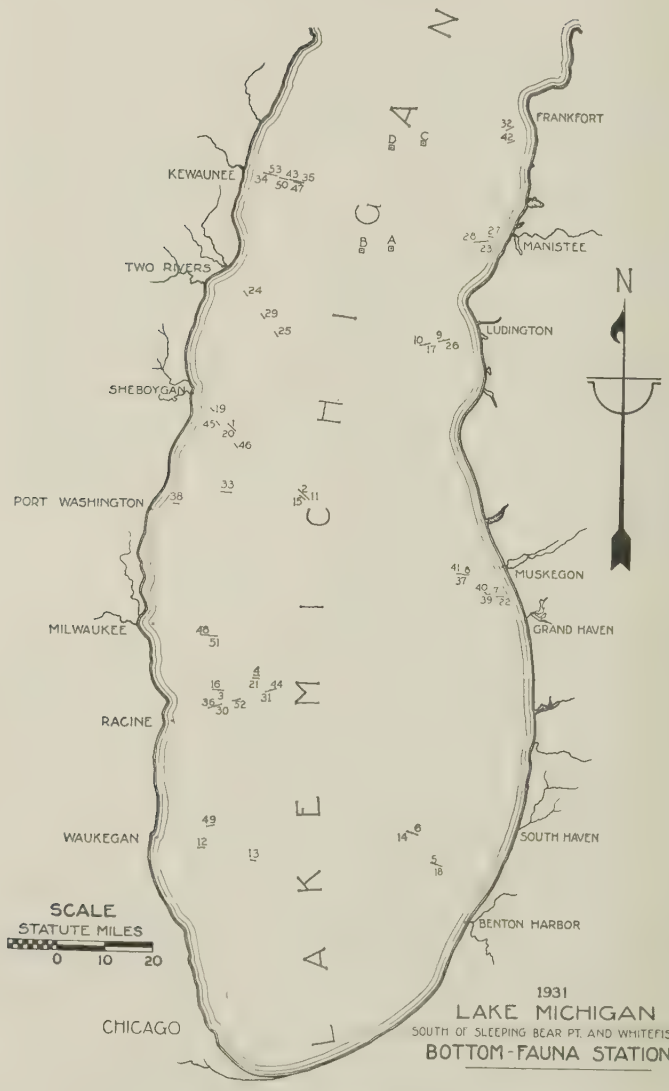
The present work represents part of a general program, the main problem of which was concerned with the operation of certain experimental chub nets. Collection and study of the bottom fauna was undertaken partly for its own sake, partly with the hope that it might yield information relative to factors that possibly influence the movements of chubs and lake trout. The whole program was planned by and was under the general direction of Dr. John Van Oosten, who placed Mr. Hilary Deason, assistant aquatic biologist, in charge of the field work. Other scientist members of the field party were Dr. Ralph Hile, assistant aquatic biologist; Mr. Frank Jobes, junior aquatic biologist; Mr. Frank Lathrop; and Mr. Walter Sauer. To each of these, but especially to Dr. Van Oosten and to Mr. Deason, the writer is greatly indebted for much help, advice, and information. The writer is not connected with the Bureau of Fisheries, but was generously invited by Dr. Van Oosten to study the bottom-fauna collections.

Distribution of the Samples

As Map 40 indicates, all the 1931 samples were taken south of a line drawn from Frankfort, Michigan, to Algoma, Wisconsin. Numbers refer to the position of the stations; bars beside them show the location of experimental chub nets. The deepest water was encountered at Stations A, B, C, and D, between Frankfort and Manistee, Michigan, and Two Rivers and Kewaunee, Wisconsin.

During the early part of the 1932 season samples were taken only in Green Bay. Later in that year the sampling was extended to include both Green Bay and the northern end of the open lake. In Map 41 numbers and positions of bottom-fauna and of experimental gill-net stations are indicated as in Map 40. As in the former year, the deepest water was found between Frankfort, Michigan, and Kewaunee, Wisconsin, and Stations A and B show where these deepest-water bottom samples were taken in 1932. The greatest depth within Green Bay from which bottom samples were collected was at Station 25, where the water was 46 meters deep, and the shallowest was at Station 12, where the depth was only 24 meters.

The total number of samples collected during the two seasons of 1931 and 1932 was 167. The depths from which they were drawn



Map 40. Location of bottom-fauna stations and experimental gill nets in Lake Michigan during the 1931 season

MAP 41. Location of bottom-fauna stations and experimental gill nets in Lake Michigan and Green Bay during the 1932 season

range from 24 to 246 meters. Figure 30 makes it plain, however, that most of these were distributed between depths of 24 and 150 meters, with only a scattered few below the greater depth.

Certain data relative to the distribution of the 1931 samples have been arranged in Table I. The 49 different depths from which they

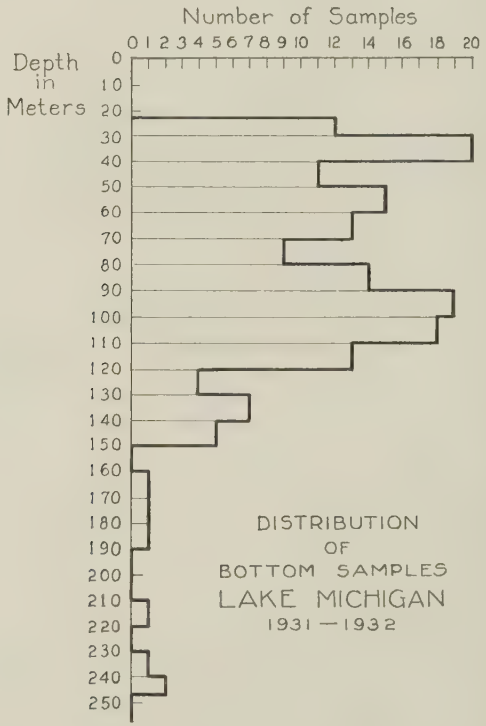


Fig. 30. Distribution, according to depth, of bottom-fauna samples collected in Lake Michigan in 1931 and 1932

were collected are indicated in the first column and, in addition, the whole table has been divided by a series of 15 horizontal lines so drawn that they separate from those adjacent to them the data pertaining to each 10-meter stratum. In the second column the first vertical line of figures lists the number of samples from each depth, and the second file of figures in that column states the total number of samples

TABLE I

DISTRIBUTION OF DEEP-WATER BOTTOM-FAUNA SAMPLES, LAKE MICHIGAN, 1931

Depth in meters	Number of samples	Dates (between May 11 and Nov. 2, 1931)	Stations
40	1	Aug. 17	22E
44	1	Aug. 7	22E
45	1	July 18	22E
47	1 (4)	July 30	32E
52	2	May 14; Aug. 18	7E, 26E
53	1	Aug. 26	26E
54	1	July 1	18E
55	1	May 12	5E
56	2	May 11; June 30	12E, 12E
57	2	June 9, 18	18W, 18E
58	1	Aug. 19	32E
59	1 (11)	Aug. 27	32E
62	1	Sept. 18	9W
63	3	May 15, 27; Sept. 29	9W, 5W, 40W
68	2 (6)	Aug. 31; Oct. 22	38E, 49W
70	1	Aug. 6	30W
75	1	Nov. 2	49E
77	2 (4)	June 1, 27	15W, 15E
83	2	June 25; July 8	25E, 29E
84	2	May 26; Sept. 23	13W, 45E
87	5	May 12, 27; June 30; July 8; Aug. 3	14E, 14E, 13E, 25E, 25W
88	1 (10)	May 11	13E
90	1	July 6	23 midpoint
91	1	Aug. 26	17E
95	3	June 9, 18; July 1	14W, 14W, 14W
96	1	July 18	8E
97	3	May 23; June 15; July 10	4E, 21W, 21E
98	3 (12)	May 14; June 29; Aug. 18	8E, 21W, 17E
100	1	June 22	8E
101	1	July 20	17E
103	1	Aug. 6	31W
106	1	Sept. 28	44W
107	4	Aug. 17; Sept. 29; Oct. 9, 21	37W, 41W, 44W, 44W
108	2	Sept. 3, 4	41E, 17E
109	2 (12)	July 3, 17	17E, 31E
116	2	July 9; Sept. 18	20W, 17W
119	1 (3)	June 24	23W

TABLE I (*Continued*)

Depth in meters	Number of samples	Dates (between May 11 and Nov. 2, 1931)	Stations
133	1	Sept. 23	46E
135	1	May 19	10E
138	1	June 13	20E
139	1 (4)	July 24	33E
144	1	June 11	17W
145	1	Oct. 5	47W
146	2 (4)	Aug. 13; Sept. 11	33E, 38E
163	1 (1)	Aug. 12	35E
172	1 (1)	Oct. 15	47E
189	1 (1)	July 22	32W
220	1 (1)	June 24	A
244	1 (1)	July 30	C

SUMMARY. — 75 samples, from 49 different depths, ranging from 40 to 244 meters, taken between May 11 and November 2, 1931, at 49 different stations.

collected within each of the 10-meter strata. These figures have been enclosed by parentheses. Thus between the depths of 40 and 49 meters 4 samples were taken; 11 between 50 and 59 meters; 6 between 60 and 69; and so forth. Sampling was begun on May 11 and continued intermittently throughout the spring, summer, and autumn until November 2. Since the data in the table have been arranged in order of increasing depth instead of chronologically, the first line relates to a midseason collection rather than to the first one of the year. In several instances two or more stations were located in water of identical depth, although usually such stations were more or less widely separated. The two samples from 52 meters illustrate this fact. The first sample of the season to be taken at that depth was collected on May 14, at Station 7E, which was located off the eastern shore of the lake between Muskegon and Grand Haven, Michigan. The second sample from 52 meters to be taken that year was not drawn until August 18, when the field party was at Station 26E, approximately 60 miles away to the north and about 7 miles offshore abreast of Ludington, Michigan. However, not in all instances where

the table indicates that samples from a particular depth were taken on different dates was it true that they were likewise from different stations. For example, three samples were hauled from a depth of 95 meters, one each on June 9, June 18, and July 1; but all three came from Station 14W. The letters appended to the station numbers have the following significance: "E" indicates that the bottom-fauna station was at the eastern end of a gang of nets bearing the corresponding number; "W," that the station was at the western end of the nets. The distance from "E" to "W" was approximately one mile. The summary of the table states that the samples were drawn "from 49 different depths . . . at 49 different stations." This is merely a coincidence, since many different stations widely separated in the lake chanced to have identical depths.

Table II contains data for the 1932 season, arranged in the same manner as are the 1931 data in Table I. Several significant differences exist between the distribution of the samples in the two years. Whereas in 1931 the shallowest depth from which samples were drawn was 40 meters, in 1932 sampling extended over a range in depth of from 24 to 246 meters, with nearly one third of all the samples taken that season collected in water less than 40 meters deep. During 1932 no samples were collected between 144 and 240 meters, but in 1931 several samples were taken from rather uniformly distributed depths between the same two contours. In 1932 field work began earlier in the spring and likewise ceased earlier in the autumn than it did in 1931. In fact, although the 1932 season began almost a month earlier, it was actually just one month shorter, the two seasons extending over, approximately, six-month and five-month periods, respectively. As in Table I, the letters appended to the station numbers in Table II show the direction in which the net gangs were set and indicate at which end the bottom-fauna station was located.

The Benthic Fauna

The 1931 samples have been completely sorted, and some of the data tabulated, but only a few of the 1932 collections have been studied thus far. From that part of the work which has been finished one fact stands out very clearly, namely: the number of species found is small, but the number of individuals is large. This fact agrees with similar findings in studies of the profundal fauna of other lakes (Adamstone, 1924; Adamstone and Harkness, 1923; Cronk,

TABLE II

DISTRIBUTION OF DEEP-WATER BOTTOM-FAUNA SAMPLES, LAKE MICHIGAN, 1932

Depth in meters	Number of samples	Dates (between April 19 and Sept. 12, 1932)	Stations
24	1	May 17	12SE
25	3	April 29; May 10, 11	9NE, 12NW, 15NE
26	1	May 3	11NW
27	1	May 5	14SW
28	3	April 21, 22; May 18	4SE, 5NE, 19W
29	2 (11)	April 27; May 24	8NW, 19E
30	1	April 19	1NW
31	7	April 20, 20; May 2, 2, 21, 23; June 8	2NW, 3NW, 10NE 10NE, 21S, 22NW, 23SW
32	7	April 22, 28, 28; May 17, 23, 25; Aug. 12	6NE, 6SW, 6SW, 18SE, 18SE, 20N, 55E
34	1	May 9	16S
35	3 (19)	May 12, 13, 25	13NE, 17N, 23SW
41	1	May 25	24W
44	1	June 9	24E
45	1	June 8	25NW
46	2	June 13, 13	25SE, 25SE
48	2	Aug. 8, 15	55W, 57S
49	1 (8)	July 30	41NE
55	1	Aug. 20	60
58	1	Aug. 4	41NE
59	1 (3)	June 14	34N
60	1	Aug. 16	53W
62	1	June 15	29W
65	2	Aug. 2, 17	50E, 54W
66	1	July 8	35E
68	1 (6)	June 10	27E
70	1	Aug. 13	52W
75	2	July 7, 28	32SE, 45W
76	1	Aug. 8	46S
77	1	Aug. 23	57N
78	1	Aug. 9	52E
79	1 (7)	July 19	42SE
82	1	June 27	33N
83	1	June 14	33N
86	1	Aug. 22	67NW
87	1 (4)	Sept. 1	67NW

TABLE II (*Continued*)

Depth in meters	Number of samples	Dates (between April 19 and Sept. 12, 1932)	Stations
91	1	June 6	27W
93	1	July 14	38SE
94	1	June 10	27W
96	2	June 17, 29	31W, 32W
97	1 (6)	June 15	28W
100	1	July 27	43SE
101	2	June 6, 16	30E, 30E
102	1	Sept. 7	67SE
105	1	Sept. 12	63SW
106	2	July 12; Aug. 25	32NW, 65S
107	1 (8)	July 9	37NW
114	2	Aug. 5, 6	49E, 51NW
118	5	July 5; Aug. 10; Sept. 2, 3, 9	36SE, 53E, 59NW, 66NW, 59SE
119	3 (10)	June 3; Aug. 1; Sept. 10	C, 48E, 66NW
123	1	June 27	36NW
124	1	June 9	26E
128	1 (3)	June 30	35W
130	1	July 13	35W
132	1	July 9	36SE
139	2 (4)	June 3	D, 35W
144	1 (1)	Aug. 11	54E
240	1	June 2	B
246	1 (2)	June 2	A

Summary. — 92 samples, from 58 different depths, ranging from 24 to 246 meters, taken between April 19 and September 12, 1932, at 79 different stations.

1932; Decksbach, 1928; Eggleton, 1931; Juday, 1922; Lundbeck, 1926; Miyadi, 1932; Rawson, 1930; Scott, Hile, and Spieth, 1928). However, even though the number of individuals must be regarded as large, the population of the lake floor beneath the deeper waters of Lake Michigan appears never to approach the great density in some of the small inland lakes (Juday, 1922; Eggleton, 1931, 1935). The maximum number of individuals of all species found in the samples thus far studied was between 11,000 and 12,000 per square meter.

From that part of the work which has been finished there appears

to be some evidence indicating the presence of a concentration zone. Such a zone, if the completed results finally demonstrate its existence, will probably show a region of maximum abundance not far from 40 meters. Certainly the benthic population in 1931 was much more abundant between 40 and 50 meters than within any other 10-meter stratum from which samples were taken. Moreover, the depth at which the actual maximum abundance occurred in 1931 was 44 meters, and both above and below that isobath the density of the population decreased. Furthermore, among the few 1932 samples from which the animals have been sorted there appears to be some evidence of a decrease in density of population at some of the shallower depths.

ANNOTATED LIST

The list of animals found thus far is not an extensive one. Present identifications, which must be regarded as tentative, show the following forms to be present:

Pontoporeia, by far the most abundant organism; found in all but one sample; probably two species.
Tubificidae, the next most numerous animal; possibly 2 genera and 3 species.
Pisidium, possibly 3 species; not abundant.
Nematoda, 2 genera; 1 species each; common.
Ostracoda, 1 species; very few specimens.
Sphaerium, 1 species; rare.
Chironomus larvae, in small numbers in a few samples.
Hirudinea, a few specimens.
Mysis, a very few specimens.

In addition, such incidental things as Polyzoa statoblasts, ephippia, and specimens of various surface and littoral species occurred in scattered samples. Much evidence of reproductive activity on the part of the benthic animals was encountered in the form of eggs, cocoons, and embryos.

One further, isolated fact seems worthy of mention in the present report; only one sample of more than one hundred thus far sorted was entirely devoid of animals. That sample came from a depth of 163 meters and was taken on August 12, 1931, at Station 35E, about 14 miles off the Wisconsin shore and slightly south of east from Kewaunee. It is doubtful, however, whether the entire lack of animals in this one sample has any particular significance, since on other occasions both earlier and later in the season, at other depths both above and below this one, and at other closely adjacent stations, benthic

animals were present. The interesting and remarkable thing is not the absence of animals in this one sample, but their universal presence in all the others.

A further report on this study will be published at a later time, when all the material has been examined and identification of species has been properly made. At that time the seasonal variations, depth distribution, ecological relations, and other phenomena pertaining to the limnology of this deep-water benthic fauna in one of the deepest of our Great Lakes will be discussed.

Summary

1. The present paper, which is the first report on a quantitative limnological study of the deep-water benthic fauna of Lake Michigan, one of the five Great Lakes of North America, describes methods and equipment used, explains the temporal and geographical distribution of the sampling, and discusses some of the general biological features of the fauna.

2. Samples were collected throughout the spring, summer, and autumn of 1931 and 1932. This part of the work was entirely quantitative and nearly all was done with a Petersen dredge. A total of 167 samples were taken during the two seasons. The samples were drawn from depths ranging between 40 and 244 meters in 1931, and between 24 and 246 meters in 1932.

3. This study of the bottom fauna of Lake Michigan, which is part of a larger and more general program under the direction of Dr. John Van Oosten, aquatic biologist in charge of Great Lakes Fisheries Investigations of the United States Bureau of Fisheries, was undertaken partly for its own sake, partly with the hope that it might yield information relative to factors that possibly influence the movements of chubs and lake trout.

4. Although the work has not been completed, since only a few of the 1932 samples have been studied, it is evident that the benthic population is composed of relatively few species but many individuals. The maximum abundance of individuals of all species found in the samples thus far studied was between 11,000 and 12,000 per square meter. This maximum population occurred between the depths of 40 and 50 meters during 1931.

5. A further report, to be published after all the material has been

studied, will include a discussion of seasonal variations, depth distribution, ecological relations and other phenomena pertaining to the limnology of this deep-water benthic fauna.

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LITERATURE CITED

Adamstone, F. B. 1924. The Distribution and Economic Importance of the Bottom Fauna of Lake Nipigon, with an Appendix on the Bottom Fauna of Lake Ontario. Univ. Toronto Stud., Biol. Series, 25 : 33–100; Publ. Ont. Fish. Res. Lab., 24.

—— and Harkness, W. J. K. 1923. The Bottom Organisms of Lake Nipigon. *Ibid.*, 22 : 121–170; Publ. Ont. Fish. Res. Lab., 15.

Cronk, M. W. 1932. The Bottom Fauna of Shakespeare Island Lake, Ontario. Univ. Toronto Stud., Biol. Series, 36 : 29–65; Publ. Ont. Fish. Res. Lab., 43.

Decksbach, N. K. 1928. Die Bodenbevölkerung der Seen der Meschtschera-Niederung, Gouv. Rjasan, Zentral-Russland. Zugleich ein Beitrag zur Typologiefrage. Arbeiten der biologischen Station zu Kossino, 7–8 : 87–135.

—— und Decksbach, Marie. 1931. Die Bodenbevölkerung und die Bodenproduktivität des Pereslawskoje Sees. Arbeiten der Limn. Station zu Kossino, 13–14 : 131–189.

Eggleton, F. E. 1931. A Limnological Study of the Profundal Bottom Fauna of Certain Fresh-Water Lakes. Ecol. Mon., 1 (3) : 231–331.

—— 1935. A Comparative Study of the Benthic Fauna of Four Northern Michigan Lakes. Pap. Mich. Acad. Sci., Arts and Letters, 20 : 609–644.

Juday, C. 1922. Quantitative Studies of the Bottom Fauna in the Deeper Waters of Lake Mendota. Trans. Wis. Acad. Sci., Arts and Letters, 20 : 461–493.

Lundbeck, J. 1926. Die Bodentierwelt norddeutscher Seen. Arch. für Hydrobiol., Suppl., 7 : 1–473.

Miyadi, D. 1932. Studies on the Bottom Fauna of Japanese Lakes. VII. Lakes of Hokkaidô. Japanese Journ. Zool., 4 (3) : 223–252.

Rawson, D. S. 1930. The Bottom Fauna of Lake Simcoe and Its Role in the Ecology of the Lake. Univ. of Toronto Stud., Biol. Series, 34 : 1–183; Pub. Ont. Fish. Res. Lab., 40.

Scott, Will, Hile, R. O., and Spieth, H. T. 1928. Investigations of Indiana Lakes. A Quantitative Study of the Bottom Fauna, Lake Wawasee (Turkey Lake). Dept. Conserv. St. Ind., Publ. Div. Fish and Game. Indianapolis, 1 : 1–25.

FIG. 1

FIG. 2

FIG. 1. Petersen dredge, meter wheel, davit, and steel cable. Dredge is open and about to be lowered. Photograph by Michigan Department of Conservation

FIG. 2. General view forward along deck of United States Bureau of Fisheries' motor ship *Fulmar*, showing Petersen dredge and winch, steel cable, davit, and meter wheel by which the dredge was lowered and raised. Photograph by Michigan Department of Conservation

On board United States Bureau of Fisheries' motor ship *Fulmar*. Members of United States Bureau of Fisheries' field party washing fine mud and sand from bottom-fauna samples. Photograph by *Milwaukee Journal*

THE RELATION OF THE KNOBBED ANAL KEELS TO AGE AND SEX IN THE LINED SNAKE *TROPIDOCLONION LINEATUM* (HALLOWELL) *

EDITH R. FORCE

THE attention of the writer was called by Dr. F. N. Blanchard [1] to the occurrence of knobs on the keels of scales near the anal region in the lined snake *Tropidoclonion lineatum*. Studies by this author (1) show that these structures characterize the adult males of certain species of snakes of the genus *Natrix*, and a later study by Marjorie Brown Harrison (3) has shown this to be true in the garter snake *Thamnophis sirtalis sirtalis*. Since the present writer had on hand a large series of lined snakes, numbering 608, it was decided to check the occurrence of the knobbed keels in this species. Most of the collection used was obtained during the months from March to June in the years from 1926 to 1932. It included, however, a considerable number of young born in August and a few larger specimens taken at various times in other seasons.

The knobbed keels in *Tropidoclonion* appear to be the same as those already described in *Thamnophis*, except that they are correspondingly smaller, as is to be expected in the smaller species. Satisfactory determination of the presence or the absence of the knobs requires the use of such magnification as is provided by a low-power binocular microscope.

Examination of all the males available showed well-developed knobbed keels to be present in 130 individuals over 185 mm. in total length, and to be lacking in only 4 of this size. In 4 others they were only faintly visible. Of individuals 185 mm. or shorter 67 lacked the

* A contribution from the Biological Station of the University of Michigan and Woodrow Wilson Junior High School, Tulsa, Oklahoma.

[1] The writer desires to express her appreciation to both Dr. F. N. Blanchard and Dr. Frieda Cobb Blanchard for their courtesy in criticizing the manuscript of this paper.

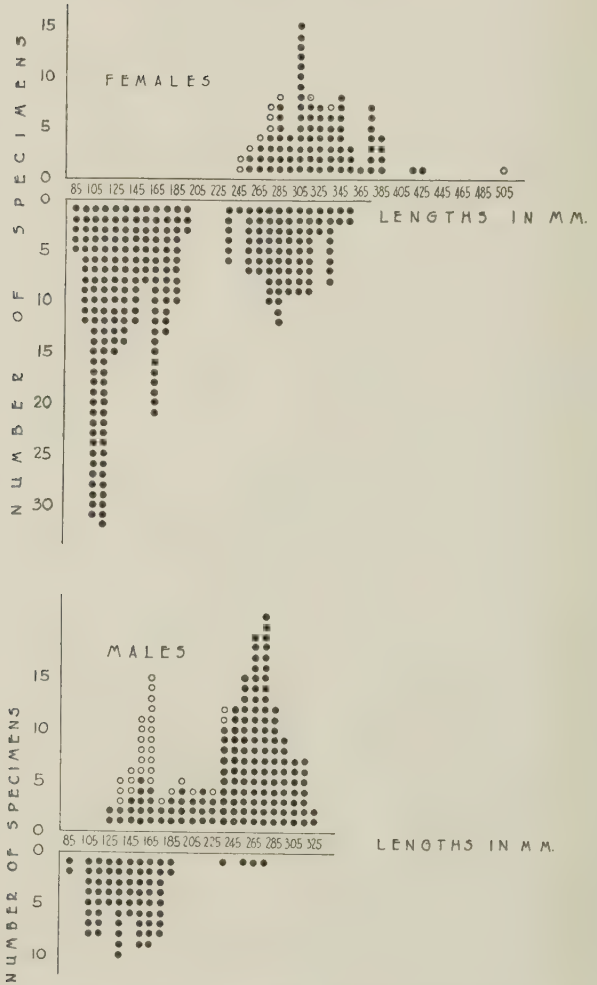

FIG. 31. Diagrams showing the relation between total lengths in females and males and the presence or the absence of knobbed anal keels. Specimens possessing these structures well developed are plotted above the abscissa; those lacking them, below. Cases in which the knobs were only faintly visible are represented by circles instead of dots. Individuals included in the group from 81 to 90 mm. are classed at 85 mm.; those from 91 to 100 mm., at 95 mm., etc.

knobs entirely, 18 possessed them well developed, and 27 more had them barely visible. These results are given graphically in Figure 31.

The males have been divided on the basis of their possession of distinctly defined knobbed anal keels into two well-marked groups, one of larger individuals and the other of smaller ones. In the group of larger individuals 97 per cent possessed well-defined knobbed anal keels. The group of smaller individuals may be observed to have two subgroups: (*a*) those from 85 to 125 mm., which wholly lack knobbed anal keels; (*b*) those from 125 to 185 mm., fifty per cent of which possess anal keels more or less conspicuously knobbed.

It is significant that the groups based upon the presence of knobbed anal keels are practically identical with the age groups obtained in an earlier study of this species (2). In that study it was shown that there were no individuals more than 125 mm. in length at birth; that those from 120 to 200 mm., which were probably in the second season of growth, were assuming characteristics of maturity, as determined by dissections; and that those of 240 mm. and over were probably of reproductive size and age. By comparison of the groups mentioned above, the one based on the occurrence of knobbed anal keels and the other on age, it will be seen that the newly born snakes are without knobs; that juveniles may or may not have them; and that practically all males have well-developed knobs at the time that they reach sexual maturity. It is evident, then, that these structures develop concurrently with the sex organs, and that they reach their full development by the time sexual maturity is attained, or sooner.

The size group in which the knobs develop in males, that from 125 to 185 mm. in length, is composed mainly of snakes in their second season of growth. It has been concluded in an earlier study (2) that this species is sexually mature the second spring after birth (which occurs in August or September). Although it is quite possible that this group may include a few snakes very small at birth, which have reached this length only after an additional season of growth, and others which, perhaps larger at birth, grew so slowly that they did not pass on with the group at the end of the first season, yet it may be assumed that the majority of the individuals of this group are in their second [2] full season of growth. Since some of the smallest members of

[2] The first season is interpreted as the time after birth in the autumn. The second season refers to the period from the following spring to the next autumn inclusive.

the group, collected presumably in their first spring, show faintly developed or even well-developed keels, whereas the newly born snakes never do, it may be assumed that the knobs develop in the first spring, when the snakes first begin to grow rapidly in length. Although it does not always start in the spring, it is uniformly completed by the close of this season. The next spring these males are sexually mature, and almost invariably have the knobs.

In the females the situation proved to be somewhat different from that expected on the basis of conditions found in other genera. Of those over 195 mm. in length 77, or about half of the total number, showed distinct knobs on the dorsal keels of the anal region, 11 showed them faintly, and 84 lacked them entirely. Of the females less than 195 mm. in length all (176) were without them (Fig. 31). As with the males, the females are divided into two well-marked groups by their possession of knobbed keels. These groups correspond to the age groups of the earlier paper. In the females, however, the group of smaller individuals without a trace of knobs consists of the juveniles of the second season as well as the newly born snakes. The group of larger snakes, those which frequently have knobs, are adults. It will be observed that in both sexes there is a distinct connection between age, or degree of maturity, and knobbed anal keels; but, as has been said, in the males the knobs develop during the juvenile stage and are always present at the time that sexual maturity is attained, whereas in the females they are never found in the juveniles or young, and if they develop at all it is only when the individual is a well-matured adult.

It will be noticed (see Fig. 31) that the mode and the average length of the females bearing knobs are decidedly above those of the females without them; further, that of those over 335 mm. in length 25 females have knobs, whereas only 4 lack them, and that if they grow to be more than 355 mm. (15 specimens recorded) all females have knobs.

It is evident that the knobs, which indicate the approach of maturity in the male, denote in the female an approach to old age. If the structures are classed as secondary sex characters in this genus, as in other genera of snakes in which they have been studied, they are distinctly less strictly so. Of course, their occurrence in well-matured females does not preclude this interpretation, since there are instances of a secondary sex character of the male becoming an old-age character of occasional females.

SUMMARY

The young of *Tropidoclonion lineatum* are born in August or September. The following spring the males may begin to develop knobs on the dorsal keels in the anal region. About one half of the juvenile males collected in their first spring have knobs, either faintly visible or well developed. By the end of this season the knobs are almost invariably fully developed. The next spring the snakes are sexually mature.

In females the knobs are sometimes present, but not in juveniles. None but sexually mature individuals, and only about half of these, have knobs. Moreover, it is the larger, and doubtless older, adults which have them. Of the 29 largest ones collected all but 4 have knobs; of those over 355 mm. all (15) have knobs.

In males, developing knobs indicate the approach of sexual maturity; in females, if knobs occur, they denote, rather, old age. If, as in other genera of snakes studied, this character is considered a secondary sex character of males, it is less strictly so in *Tropidoclonion* than in other genera.

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LITERATURE CITED

1. Blanchard, Frank N. 1931. Some Secondary Sex Characters of Certain Snakes. Bull. Antivenin Inst. Am., 4 : 95–104, figs. 1–11.

2. —— and Force, Edith R. 1930. The Age of Attainment of Sexual Maturity in the Lined Snake, *Tropidoclonion lineatum* (Hallowell). *Ibid.*, 3 : 96–98, figs. 1–3.

3. Harrison, Marjorie Brown. 1933. The Significance of Knobbed Anal Keels in the Garter Snake, *Thamnophis sirtalis sirtalis* (Linn.). Copeia. No. 1 : 1–3.

SUMMARY OF INVESTIGATIONS ON THE MORPHOMETRY OF THE CISCO, *LEUCICHTHYS ARTEDI* (LE SUEUR), IN THE LAKES OF THE NORTHEASTERN HIGHLANDS, WISCONSIN *

RALPH HILE

INTRODUCTION

THE morphometric studies on the cisco or lake herring, *Leucichthys artedi* (Le Sueur), which will be summarized briefly in this paper are part of a program of investigation of the fishes of the lakes in the northeastern highland district, Wisconsin, conducted coöperatively by the Wisconsin Geological and Natural History Survey and the United States Bureau of Fisheries. For the morphometric studies 1,548 specimens were employed, all of them collected in the summers of 1931 and 1932 from four "type" lakes, selected on the basis of their size, depth, and physicochemical and biological characteristics. Of this number 753 individuals were used to determine the general nature of the morphological variations in the Trout Lake, Muskellunge Lake, Silver Lake, and Clear Lake cisco populations, while 795, collected from Muskellunge Lake in 1932, were employed in a detailed examination of certain morphological differences between the 1928 and 1929 year classes of that population. Limitations of space necessitate the omission of many interesting facts brought out by the rather voluminous data. An attempt will be made, however, to present in this paper all the more important conclusions, together with a small amount of illustrative material. A complete presentation of the material will be published elsewhere.

Of the four populations studied, three (those from Muskellunge Lake, Silver Lake, and Clear Lake) were assigned by Koelz (1931) to the subspecies *clarensis*. The cisco population of Trout Lake was

* Published by permission of the Commissioner of Fisheries.

included by the same author under the subspecies *clemensi*. Clear Lake is the type locality for *clarensis*.

The purposes of the morphometric studies were the determination of: (1) the range of variation of morphometric characters within single cisco populations; (2) the extent of morphological differences between populations of the same and of different subspecies; and (3) the extent of morphological differences between populations and between year classes of a single population, traceable to the direct modifying effects of the environment. Under (1) may be included the questions of sex differences and of the change of body proportions with growth. The third purpose listed includes the important problem of the relationship between growth rate and body form. Extensive data on the growth histories of each of the four cisco populations are available from my studies on the growth of these fish (Hile, MS). Further, the individual growth history of each of the 753 individuals employed in the general morphometric survey was determined from the assessment of age and the calculation of past growth, based on scale examinations and measurements.

RANGE OF VARIATION

Table I shows the mean value for each cisco population for each of the morphometric characters included in the study. In the same table may be found the total range in the value of each morphometric character for each of the subspecies, *clemensi* (Trout Lake) and *clarensis* (Muskellunge, Silver, and Clear lakes). The data of the table show that the four populations exhibit large differences with respect to most of the characters considered. These differences are sufficiently great to indicate that each population must be considered morphologically distinct. Likenesses between any two populations with respect to one character are offset by differences with respect to other characters. It should be pointed out further that, on the whole, the Muskellunge Lake and the Silver Lake populations, assigned by Koelz (1931) to the subspecies *clarensis*, resemble the Trout Lake population, assigned by the same author to the subspecies *clemensi*, more closely than they resemble the population from the *clarensis* type locality, Clear Lake (Pl. LXII, Figs. 1 2). A comparison of the morphological characters of the three *clarensis* populations of this study (Table I) with Koelz' (1931) key to the subspecies of *artedi* shows that these three populations, assigned

TABLE I

AVERAGE VALUE OF MORPHOMETRIC CHARACTERS FOR EACH OF THE FOUR CISCO POPULATIONS; TOTAL RANGE OF VARIATION FOR EACH CHARACTER IN THE SUBSPECIES *CLEMENSI* (TROUT LAKE) AND *CLARENSIS* (MUSKELLUNGE LAKE, SILVER LAKE, AND CLEAR LAKE)

Abbreviations: L = standard length; H = head length; D = greatest body depth; W = greatest body width; AT = adipose to caudal distance; DCP = least depth of the caudal peduncle; DB, AN = dorsal and anal fin bases; AD = length of adipose fin; PV = pectoral-ventral distance; E = antero-posterior eye diameter; AV = anal-ventral distance; S = length of snout; M = length of maxillary; P, V = length of pectoral and of ventral fins; DH = height of dorsal fin; R = gill rakers on first arch; Sc = lateral line scales; RD = scale rows above lateral line; RC = scale rows about the peduncle; BR = branchiostegal rays; DR, AR, PR, VR = dorsal, anal, pectoral, and ventral fin rays.

Character	Mean for population				Range for subspecies	
	Trout	Muskellunge	Silver	Clear	*clemensi*	*clarensis*
L/H *	3.85	4.19	4.38	4.49	3.43– 4.21	3.55– 5.21
L/D	4.27	4.72	4.39	3.66	3.62– 4.90	2.84– 5.69
L/W *	9.17	8.97	8.52	6.65	6.82–12.71	4.43–11.79
L/AT	8.32	8.02	7.67	8.40	6.50–12.45	6.55–10.65
L/DCP	12.67	14.15	13.49	11.54	10.62–16.17	8.88–15.91
L/DB	9.77	9.87	9.53	8.29	7.10–11.73	6.98–12.57
L/AN	9.24	10.00	9.43	9.30	6.86–10.86	7.85–12.43
L/AD	14.43	13.92	13.51	14.29	11.17–18.25	10.65–20.62
L/PV	3.53	3.58	3.40	3.23	3.08– 4.13	2.82– 4.13
L/E *	14.76	15.43	18.39	21.19	10.31–18.00	12.54–27.27
PV/AV	1.13	1.14	1.19	1.14	0.92– 1.35	0.94– 1.40
H/S	4.15	4.38	4.15	4.48	3.50– 5.00	3.42– 5.57
H/E	3.83	3.68	4.17	4.73	3.18– 4.80	2.92– 5.91
H/M *	2.94	3.16	3.11	3.42	2.44– 3.25	2.73– 3.94
D/E	3.46	3.30	4.19	5.86	2.62– 4.70	2.58– 8.45
PV/P *						
male	1.65	1.82	1.82	2.05	1.42– 1.89	1.55– 2.39
female	1.71	1.87	1.96	2.16	1.37– 2.00	1.63– 2.57
AV/V *						
male	1.49	1.66	1.59	1.87	1.23– 1.92	1.38– 2.19
female	1.51	1.70	1.67	1.95	1.26– 1.77	1.37– 2.31
DH/DB *	1.76	1.54	1.54	1.31	1.37– 2.15	1.02– 1.87
R	46.6	45.4	45.1	48.4	39.0– 52.0	39.0– 53.0
Sc	72.5	79.5	78.5	77.9	60.0– 88.0	68.0– 86.0
RD	7.2	7.6	7.6	8.5	6.0– 8.0	7.5– 9.5
RC	20.8	22.0	21.6	24.3	19.0– 23.0	21.0– 26.0
BR	8.4	8.1	8.6	8.8	7.0– 10.0	7.0– 10.0
DR	12.0	12.1	12.0	11.8	11.0– 13.0	10.0– 13.0
AR	12.1	13.0	13.2	12.4	11.0– 13.0	8.0– 15.0
PR	15.0	15.5	15.6	15.1	13.0– 17.0	12.0– 17.0
VR	12.0	11.9	12.2	12.0	11.0– 14.0	11.0– 14.0
Number of specimens	277	110	210	156	277	476

* Characters correlated with growth rate (see p. 624).

by that author to the same subspecies, exhibit structural differences that are greater than those upon which the separations of many of his subspecies have been based.

The range of variation is very large for most of the characters. The great range in the *clarensis* group depends in part on the combination of three dissimilar populations, but the data for the subspecies *clemensi*, based on the Trout Lake population alone, show how widely certain characters may vary within a single stock. This high degree of variability makes the use of large numbers of specimens necessary to obtain reliable average values for most morphometric characters. It is of interest to note that much of the systematic work that has been done on *L. artedi* was not based on large numbers of specimens. Of the seventeen new subspecies of *artedi* described by Koelz (1931) eleven were based on twenty fish or fewer, and six of these eleven on from five to ten specimens. When it is considered that in the light of intensive study the subspecies *clarensis* and *clemensi*, whose descriptions were based on 46 and 84 specimens respectively, fail to stand apart as clearly distinct groups, much skepticism is aroused concerning the validity of numerous other currently recognized subspecies of *artedi*.

Further doubt is thrown on the validity of the data employed in the current systematics of *L. artedi* by the fact that certain body ratios used as diagnostic characters show distinct tendencies to change with increase in age and size. In each of the four cisco populations the relative lengths of the paired fins were found to increase slightly with growth. Other characters that changed with growth were relative greatest body width, relative greatest body depth, relative depth of the caudal peduncle, and the anteroposterior eye diameter in greatest body depth. However, none of these last-named characters showed the same direction of change for all populations. For example, it may be seen (Table II) that relative body depth decreases with growth in the Muskellunge Lake cisco, changes only slightly in the Trout Lake and the Silver Lake ciscoes, and increases with growth in the Clear Lake cisco. It is obvious that body ratios that show marked change with growth are of limited systematic value, particularly if the change proceeds in different directions in different populations.

The chief weakness in the use, for systematic studies, of characters that change in value with growth lies in the difficulty of making

definite comparisons between any two populations. Average values for single populations have little significance, since they must not only be affected by the selective action of the gear employed in taking the sample, but may also be expected to vary from year to year according to the size and age composition of the population. These difficulties cannot be circumvented by limiting comparisons to fish of the same length. Yet, it is well known that ratios that have been shown by this study to change in value with growth have been used as important characters in the current systematics of *L. artedi*.

TABLE II

CHANGE OF RELATIVE BODY DEPTH, L/D, WITH INCREASE IN AGE IN THE FOUR CISCO POPULATIONS

The figures in parentheses show the number of specimens.

Lake	Age group										
	0	I	II	III	IV	V	VI	VII	VIII	IX	X
Trout	4.98	...	4.25	4.24	4.30	4.28	4.25	4.08	4.10	4.17	...
	(17)		(11)	(44)	(130)	(56)	(10)	(4)	(3)	(2)	
Muskellunge..	...	...	4.43	4.82	...	...	...	...	...	...	...
			(29)	(81)							
Silver.....	...	4.64	4.53	4.38	4.35	4.37	4.37	4.69	...	...	...
		(14)	(7)	(38)	(67)	(70)	(13)	(1)			
Clear.....	...	4.38	3.79	3.62	3.52	3.60	3.31	3.44	3.52	...	...
(male)		(10)	(15)	(20)	(6)	(9)	(5)	(12)	(1)		
Clear.....	...	4.25	3.74	3.58	3.68	3.57	3.22	3.30	3.31	3.35	3.05
(female)		(10)	(11)	(20)	(8)	(4)	(5)	(10)	(7)	(2)	(1)

Sexual dimorphism with respect to the paired fins was found in all populations. These sex differences with respect to the relative length of the fins are more pronounced in the pectoral fins than in the ventral fins, and in the older age groups than in the youngest, where the two sexes have fins of approximately the same length. The current systematics of *artedi* has made use of the relative length of the paired fins, but has done so without reference to sex differences. If the sex ratio could be considered constant at all ages and in all populations, the errors resulting from disregard for sex differences in fin length would not be important. However, I showed in my study of the growth of the cisco that the sex ratio not only

varies widely from one population to another but also is subject to marked change within a single stock with increase in the age of the specimens. Consequently two samples from the same or from different populations may show dissimilarities that depend only on differences in the proportions of the sexes in the samples.

Other sex differences found in the cisco were limited to the Clear Lake population, in which the females possess wider and deeper bodies and slightly smaller eyes and heads than the males.

GROWTH RATE AND BODY FORM

When the four cisco populations of this investigation are arranged according to the average value of certain body ratios (marked with asterisks in Table I) they fall in the same order that they show with respect to their rates of growth. The correspondence is such that more rapid growth is associated with relatively shorter heads, maxillaries, paired fins, and dorsal fins, wider bodies, and smaller eyes (anteroposterior diameter in body length). The nature of this apparent correlation between growth rate and body form may be made clearer by examination of data on the growth rates of the four populations.

Tables III and IV present the data on the growth in length and weight respectively. It may be seen that the Clear Lake cisco has the best growth and the Trout Lake cisco the poorest with respect to both length and weight. The growth rates of the Muskellunge Lake cisco and the Silver Lake cisco are intermediate to these two extremes. Since the Muskellunge Lake cisco grows more rapidly in length than the Silver Lake cisco, though the latter has the better growth in weight, it is difficult to decide which of the two stocks does grow the more rapidly. For the purposes of this study, however, it may be considered that, if the Clear Lake cisco has the highest average value for a body ratio and the Trout Lake cisco the lowest (or the reverse), while the Silver Lake and the Muskellunge Lake populations show intermediate and similar values, then there is correlation between growth rate and that particular character.

The observed correspondence between growth rate and certain body ratios suggests the possibility that the indicated differences in body form may be, in part at least, the direct result of differences in growth rate. If such a direct relationship between growth rate and body form does exist, it may be expected that an analytic study

TABLE III

Average Calculated Standard Length in Millimeters at the End of Each Year of Life in the Trout Lake, Silver Lake, Muskellunge Lake, and Clear Lake Cisco Populations

Only the Clear Lake cisco shows differences in the growth (in length) of the sexes.

Lake	Year of life												Total number of specimens
	1	2	3	4	5	6	7	8	9	10	11	12	
Trout	81	117	137	148	158	168	179	189	197	213	219	225	1182
Silver	80	129	155	169	181	189	196	...	...	...	...	...	564
Muskellunge	96	143	161	174	...	...	...	...	...	...	...	...	1097
Clear (male)	110	196	255	287	308	323	335	345	354	...	...	...	216
Clear (female)	109	199	260	291	312	326	340	351	361	369	376	...	224

TABLE IV

Weight in Grams of the Different Age Groups of the Trout Lake, Silver Lake, Muskellunge Lake, and Clear Lake Cisco Populations

Except for a tendency for the Silver Lake males to be very slightly heavier than females of corresponding age, the Clear Lake cisco is the only population to show sex differences as to growth in weight.

Lake	Age group												Total number of specimens
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Trout	..	31	37	41	47	50	...	111	....	....	119	172	933
Silver	..	59	68	78	93	104	...	...	....	....	....	...	364
Muskellunge	..	46	51	60	...	...	...	...	....	....	....	...	987
Clear (male)	71	267	418	578	647	673	729	796	880	....	....	...	186
Clear (female)	80	306	530	705	770	841	917	950	1085	1062	1190	...	198

of a single population may reveal a correlation between individual growth rate and individual body form. Such analyses were conducted with respect to each ratio that showed an apparent correlation with growth rate. The details of these analyses cannot be presented in the space available here. However, the material of Table V will serve to illustrate the arrangement of data upon which the analyses were based.

TABLE V

VARIATION OF THE RATIO, L/H, IN THE CLEAR LAKE CISCO, 193[illegible] ACCORDING TO LENGTH AND AGE

The figures in parentheses show the number of specimens. The sexes are combined.

Length interval in millimeters	Age group									Average
	I	II	III	IV	V	VI	VII	VIII	IX	
140–59	4.53 (1)	...	...	...	...	...	...	...	...	4.53 (1)
160–79	4.54 (11)	...	...	...	...	...	...	...	...	4.54 (11)
180–99	4.46 (3)	...	...	...	...	...	...	...	...	4.46 (3)
200–19	...	4.44 (1)	...	...	...	...	...	...	...	4.44 (1)
220–39	...	4.48 (1)	...	...	...	...	...	...	...	4.48 (1)
240–59	...	4.65 (5)	4.13 (1)	...	...	...	...	...	...	4.56 (6)
260–79	...	4.70 (5)	4.39 (2)	...	...	...	...	...	...	4.61 (7)
280–99	...	...	4.57 (8)	...	3.96 (1)	...	...	...	...	4.50 (9)
300–19	...	...	4.76 (14)	4.45 (3)	4.57 (2)	4.26 (2)	4.26 (1)	...	...	4.63 (21)
320–39	...	...	...	4.58 (6)	4.59 (5)	...	4.39 (6)	4.23 (1)	...	4.50 (18)
340–59	...	...	...	...	4.49 (2)	...	4.49 (5)	4.29 (4)	4.47 (1)	4.42 (12)
360–79	...	...	...	...	...	...	4.50 (1)	4.34 (1)	4.48 (1)	4.44 (3)
380–99	...	...	...	...	...	...	4.57 (1)	...	...	4.57 (1)
Average	4.52 (15)	4.64 (12)	4.64 (25)	4.54 (9)	4.57 (10)	4.26 (2)	4.44 (14)	4.29 (6)	4.48 (2)	

This table shows the values of the ratio, head in length, for the Clear Lake cisco arranged according to length and age, that is, according to rate of growth. If the variations of L/H are examined, it may be seen, first, that in general the ratio increases with increase in length in fish of a single age group, and, secondly, that L/H decreases with increase in age in fish of a single length interval. In other words, the more rapidly growing fish within the population have the relatively smaller heads, regardless of whether the comparisons are based on fish of different lengths in the same age group or on fish of different ages in the same length group. It is true that the data exhibit certain exceptions to the general trend, but these exceptions can be explained as the result of the small number of specimens in certain groups, and can be demonstrated statistically to be of no significance. A similar relationship between relative head size and growth rate was found to exist in each of the other three cisco populations.

The studies on the relationship between growth rate and body form showed further that the more rapidly growing fish within single populations tend to possess the relatively smaller eyes and the relatively shorter maxillaries, paired fins, and dorsal fins. However, in spite of the apparent relationship between growth rate and relative body width, indicated by the averages for the entire samples of the four populations, the analysis of single populations failed to reveal any dependence of individual relative body width on individual growth rate.

Since it has been previously demonstrated by me (Hile, MS) that the growth rates of these same cisco stocks exhibit close correlation with environmental conditions, it may be concluded that environmental factors, operating through their control of growth rates, may produce extensive morphological differences between different populations of the cisco. It is probable that differences in growth rate do not account for all the differences between cisco populations of this study with respect to characters that show dependence on rapidity of growth. It must be recognized, nevertheless, that the dependence of these characters on growth rate is sufficiently marked to render them of little systematic value. The practice, common among systematic ichthyologists, of limiting comparisons to fish of approximately the same length offers no guarantee that the materials are really comparable, for fish of exactly the same size may have

widely different growth rates, and hence show pronounced but nongenetic differences in the characters that exhibit correlation with growth rate.

Five of the characters showing dependence on growth rate (relative lengths of the head, maxillary, and the paired fins, and relative size of the eye) have been employed as diagnostic characters of primary importance in the systematics of the species *artedi* (Koelz, 1931). Consequently, it must be considered probable that not a few of the *artedi* subspecies have been based on differences resulting from nongenetic differences in growth rate.

MORPHOLOGICAL DIFFERENCES BETWEEN YEAR CLASSES

In view of the apparently great sensitivity of the cisco's morphological characters to conditions of the environment, it might be expected that different year classes of the same population may exhibit, exceptionally at least, fundamental structural differences that depend on the variation from one year to another in the environmental conditions at the time of hatching and early development. Ordinarily the nature of the environment furnished by a lake does not vary greatly from year to year. However, exceptional years occur occasionally.

The data of this investigation offer one excellent example of two year classes of the same population which, though separated by only one year's difference in age, exhibit structural differences of such a fundamental nature that the individuals can be assigned readily by sight to the one group or the other. These two groups are the 1928 and 1929 year classes of the Muskellunge Lake cisco. The most striking difference between the two groups lies in the relatively much larger eye of the 1928 year class (see Pl. LXII, Fig. 3). In fresh specimens it was apparent further that the 1928 year class had a much heavier pigmentation of the dorsal region. Other differences are listed in Table VI which shows the average values, based on the 1931 collections, for each body ratio for which the two year classes exhibited statistically significant differences.

The differences indicated by the data of Table VI cannot all be considered to represent basic and permanent structural differences between the 1928 and 1929 year classes. The normal change of body proportions with growth makes it necessary to eliminate the four ratios (L/D, L/DCP, L/W, and D/E) involving measurements of

body depth and width, since the differences between the two groups with respect to these characters may be considered to depend in large measure on their differences in average length at the time of capture. The normal change of body proportions with growth does not, however, account for the differences between the two groups with respect to any of the remaining characters (L/H, L/E, H/E, H/I). It was determined further, from studies of the growth of the specimens used, that differences in the growth rates of the individuals in the samples do not account for any of the morphological differences between the 1928 and 1929 year classes.

TABLE VI

Comparison of the Samples of the 1928 and 1929 Year Classes (in the 1931 Collection) of the Muskellunge Lake Cisco with Respect to the Body Ratios for Which They Showed Statistically Significant Differences

I = interorbital width; other abbreviations as in Table I.

Year class	Age group	Number of specimens	Body ratio								Average length in millimeters
			L/H	L/D	L/W	L/DCP	L/E	H/E	D/E	H/I	
1929	II	29	4.25	4.43	8.46	13.82	16.78	3.95	3.80	4.10	147
1928	III	81	4.17	4.82	9.20	14.27	14.95	3.58	3.12	3.94	165

Further material, collected in 1932, threw some doubt on the significance of the difference between the two year classes with respect to the relative interorbital width, but otherwise substantiated the findings based on the 1931 collection. It was concluded, therefore, that the 1928 and 1929 year classes of the Muskellunge Lake cisco show basic and permanent morphological differences with respect to eye size, head length, and heaviness of pigmentation.

The comparison of the morphometric data for the 1928 and 1929 year classes of the Muskellunge Lake cisco with corresponding data for the 1930 and 1931 year class individuals occurring in the 1932 collection from that lake indicated that the differences between the 1928 and 1929 year classes with respect to head length and eye size represent a deviation of the former group from the condition normal for the population.

A single example was observed of a probably significant difference between two year classes with respect to a numerical character. The average number of gill rakers in the 1926 year class of the Silver Lake cisco (70 specimens) was 44.53, with a probable error of ± 0.16, while that of the 1928 year class (38 specimens) from the same lake was 45.84 ± 0.22. There is a strong possibility that the difference of 1.31 gill rakers is significant.

The most logical explanation of the observed morphometric differences between year classes of the same population is that they had their origin in differences from one year to another in environmental conditions during the time of early development. If the environment within a single lake can vary sufficiently from year to year to produce such marked differences as those observed between the 1928 and 1929 year classes of the Muskellunge Lake cisco, it is by no means surprising to find tremendous morphological differences between cisco populations of neighboring but dissimilar lakes. There is suggested also a strong possibility that many of the morphological differences upon which the current systematics of *L. artedi* has been based represent nothing more than the direct modifying effects of different types of environments.

CONCLUSIONS CONCERNING THE SYSTEMATICS OF *LEUCICHTHYS ARTEDI* (LE SUEUR)

On the basis of the data of the present intensive morphometric study of four populations of *L. artedi* it may be concluded that the current elaborate systematization of the species set forth by Koelz (1931) is in large measure invalid. The most important reasons for this conclusion are as follows:

(1) The differences upon which the separations of many subspecies have been based are too slight and indefinite in comparison with the wide range of natural variation of the characters used. This is particularly true with respect to those subspecies that were described from the examination of very small numbers of specimens.

(2) The values of certain characters that have been used in the separation of the subspecies show a distinct dependence on growth rate.

(3) Natural changes of body proportion with increase in length and age produce greater differences between fish of different lengths in the same population than those that have been employed in the separation of some subspecies.

(4) Permanent morphological differences between different year classes of the same population may be more extensive than the recorded differences between subspecies.

(5) Separations of subspecies on the basis of the relative lengths of the pectoral and ventral fins have been made without regard for sex differences in these characters.

The contention that the current systematics of *L. artedi* is largely without validity is not intended to imply that no genetic differences exist among the various cisco forms occurring in the glacial region of North America. The long isolation of many of them in their own peculiar and special environments must have been most conducive to the origin and preservation of genetic differences among the several stocks. The detection of these genetic differences and the determination of their extent and significance, however, provide a problem of exceptional difficulty. Obviously, the assumption commonly made by systematists, that structural differences may be taken as proof of genetic differences, does not apply within the species *artedi*. The experience of continued analytic investigations may show whether the problem can be brought to any satisfactory solution. The experimental transplantation of cisco stocks to new and different environments promises to be more critically valuable. However, pending the accumulation of adequate data for the separation of *artedi* forms according to their true and natural relationships, it would appear that the designation of a local form can be made best through a description of its salient characters and a recording of the locality it inhabits.

VARIATION IN COREGONIDS

The difficulties that beset the systematic study of *Leucichthys artedi* appear to be common to the family Coregonidae, for since the time of the earliest researches on the subject the systematics of coregonids has offered the most difficult and confusing problems to its investigators. More than seventy years ago the fundamental problems of coregonid systematics were set forth clearly by Von Siebold (1863), who pointed out the confusing effects of the direct modifying action of the local environments and of the change of body proportions with age. Unfortunately, it cannot be stated that the many subsequent researches and voluminous publications have provided any sound basis for circumventing these difficulties. For

the most part the investigators of coregonid systematics have exhibited remarkable diligence in the profuse naming of species, subspecies, and varieties, but have demonstrated little enthusiasm for the laborious and time-consuming work of determining the actual degree of soundness of their classifications. Discussions of the extreme variability of coregonids have been presented repeatedly, but contributions toward the elucidation of the causes of this variability have, in general, been lacking. Morphological differences have been assumed to be infallible indexes of genetic differences, and forms have been named indiscriminately on the most tenuous grounds. The confusion created by the general penchant for "splitting" within a highly variable and plastic group has been augmented by an almost universal propensity to revise current systematics. As a result, the recognized coregonid forms are today numbered by the hundreds, and the synonymy of many of them is nothing short of appalling.

However, distinct progress toward an understanding of the true significance of coregonid variations has been made within the last quarter century. Thienemann's publication (1912) of his studies of the coregonid introduced into the Laacher See gave a first indication of the apparently great plasticity of the group with respect to the gill rakers, a character ordinarily considered very reliable for diagnostic purposes. Further evidence for a high degree of sensitivity of gill raker number and length to environmental conditions was offered by Surbeck's study (1921) of the changes that took place in *C. Schinzii helveticus* after its introduction into the Vierwaldstättersee from the Sempacher See; by Otterstrøm's comparison (1922) of brackish water and fresh-water forms of *C. lavaretus;* and by Kreitmann's observations (1929) on the changes occurring in the lavaret (*C. Wartmanni lavaretus*) on its introduction into Le Leman from Le Bourget.

Monti's extensive studies (1929, 1930, 1933) of numerous Italian coregonid stocks, all of which originated from introductions from transalpine waters, demonstrated conclusively that, under the influence of a changed environment, coregonids may undergo extensive morphological modifications. However, these modifications are not permanent, for transplantations of the introduced forms from one Italian lake to another showed that the morphological characteristics of a single population are dependent only on the nature of the

local environment, and may be modified readily by a further change of environment.

The rapidly accumulating evidence to the effect that coregonids exhibit extensive structural modifications that represent the direct modifying effects of the environment rather than genetic dissimilarities bids fair to invalidate much of the current systematics of the group. It is quite probable that further analytic studies and transplantation experiments may show that many of the species and subspecies of coregonids recognized in Europe and America today were described on the basis of differences that are purely environmental in origin. Such artificially created groupings must inevitably fail to fulfill the primary function of taxonomy, that of setting forth phylogenetic relationships within the group. The "weeding out" of invalid species and subspecies is the most important problem confronting students of coregonid systematics today.

The simplification of the systematics of coregonids will bring about also a simplification of the problems pertaining to the evolution of the group. The previously made assumption that each of the many coregonid forms constitutes a genetically and taxonomically distinct entity has unquestionably placed unnecessarily heavy burdens on the speculative capacities of students of evolution. It is difficult to conceive how so many closely related forms could have existed as separate and distinct groups in the glacial waters of the geologically recent time of the last ice sheet. On the other hand, it is just as difficult to conceive of evolutionary development sufficiently rapid to account for the origin of the numerous present-day coregonid forms from the few basic types that might reasonably be expected to have existed in the glacial period. The most logical solution of the problem lies in the assumption that the coregonid fauna of the glacial period was represented by only a few taxonomically distinct groups, and that the number of these taxonomic groups has not increased greatly since that time. The numerous coregonid types to be observed today do not represent so many taxonomically distinct groups, but owe their existence in large measure to the fact that coregonids are subject to extensive morphological modifications which are produced by the direct action of the environment.

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LITERATURE CITED

KOELZ, WALTER N. 1931. The Coregonid Fishes of Northeastern America. Pap. Mich. Acad. Sci., Arts and Letters. 13 (1930) : 303–432. Ann Arbor.

KREITMANN, LOUIS. 1929. L'Acclimatation du lavaret du Bourget dans le Lac Leman et sa relation avec la systématique des corégones. Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie, IV : 415–434. Roma.

MONTI, RINA. 1929. Biologia dei coregoni nei laghi italiani. Rivista di Biologia, 11, Fasc. III–IV, V–VI, pp. 1–180. Milano.

—— 1930. L'Ampiezza delle variazione presentate dai coregoni italiani. Archivio Zoologico Italiano, 15 : 83–96. Napoli.

—— 1933. La genetica dei coregoni italiani e la lora variabilità in relazione coll'ambiente. Archivio Zoologico Italiano, 18, Fasc. 1–2. Napoli.

OTTERSTRØM, C. V. 1922. Heltling (*Coregonus albula* L.) og helt (*Coregonus lavaretus* L.) i Danmark. Undersøgelser af de Ferske Vandes Fiskeriforhold, 2 : 1–50. Kolding.

SURBECK, G. 1921. Beitrag zur Kenntniss der schweizerischen Coregonen. Schweizerische Fischerei-Zeitung, 29, Nr. 3, 52–59. Bern.

THIENEMANN, A. 1912. Die Silberfelchen des Laacher Sees. Zoologische Jahrbücher, Abt. für Systematik, 32 : 173–220. Jena.

VON SIELBOLD, CARL THEODOR ERNST. 1863. Die Süsswasserfische von Mitteleuropa. 430 pages. Leipzig.

FIG. 1. Typical specimens of the cisco:
(*a*) from Trout Lake (length, 122 mm.)
(*b*) from Muskellunge Lake (length, 152 mm.)
(*c*) from Silver Lake (length, 171 mm.)

FIG. 2. Typical specimens of the Clear Lake cisco:
(*a*) juvenile (length, 167 mm.)
(*b*) adult (length, 326 mm.)
(*c*) the juvenile, *a*, to a larger scale

FIG. 3. Comparison of the typical appearance of the heads of the Muskellunge Lake cisco in individuals of the 1929 year class (at left) and the 1928 year class (at right)

SING *MUSCULIUM PARTUMEIUM* SAY UNDER LABORATORY CONDITIONS

WENDELL H. KRULL

STUDENTS of trematode life histories are frequently confronted with the difficulty of securing parasite-free mollusks for infection experiments, since some mollusks are difficult to raise under laboratory conditions. During the last several years the writer has developed satisfactory methods of raising several species of mollusks; in this paper are given the steps necessary in raising *Musculium partumeium*, together with a few notes concerning its life history. The clams in this genus are of importance in parasitology, since it is known that some of the species are intermediate hosts of a number of trematodes, especially those in the genera *Crepidostomum* and *Gorgodera*.

Culture dishes (moist chambers) having a capacity of 2,000 to 3,500 c.c. make the most satisfactory aquaria in which to raise these clams. Such an aquarium is filled with water to within one inch of the top. It is then supplied with twenty to forty thoroughly dried and well-cured oak leaves which, when they have become moist, should be submerged, except a few leaves near the top in aquaria, where the maximum number of leaves is used. After it has been covered with a piece of glass, the aquarium is set aside for one month in a place where it will not be subjected to sunlight. After this lapse of time it is ready to be stocked with either young or mature clams. This method, which is the result of much experimentation, has not failed to give some degree of success in any of the numerous times it has been tried.

The following table, representing some of the cultures, shows what may be expected in the way of growth and reproduction of the clams under laboratory conditions.

The stock of clams used in the experiments was collected from ponds in the vicinity of Beltsville, Maryland. The clams are numerous in localized areas of these ponds, which are old iron-mine holes that date from the Civil War period. One pond in which the mollusks occur has a pH ranging from 5.9 to 7.8, with a yearly average pH of

TABLE I

NUMBER OF CLAMS RECOVERED FROM SOME EXPERIMENTAL AQUARIA

Aquarium	Amount of water, in c. c.	Number of oak leaves	Number of clams used in stocking	Number of days between time of stocking and examination	Clams found on examination
A	2,000	20	5 *	80	11 mature, 8 half grown, 37 less than half grown, and 15 which showed no growth
B	3,000	30	5 *	80	18 mature, 9 half grown, 47 less than half grown, and 30 which showed no growth
C	3,000	25	5 *	80	11 mature, 8 less than half grown, and 11 which showed no growth
D	2,500	36	5 *	80	24 mature, 17 half grown, 10 less than half grown, and 7 which showed no growth
E	2,000	20	13 †	69	5 mature, 1 half grown, 4 less than half grown, and 7 which showed no growth
F	2,000	20	13 †	97	5 mature, 1 half grown, 20 less than half grown, and 8 which showed no growth
G	3,000	25	2 ‡	108	9 mature, 2 half grown, 12 less than half grown, and 23 which showed no growth

* Two clams were adults; the remaining ones were immature.
† Young clams which had just been discharged from the marsupia.
‡ Mature clams.

6.6, and the other pond has a pH that ranges from 5.7 to 7.1, with a yearly average of 6.5.

Variations of the method here described for raising *Musculium partumeium* have been tried; they are summarized briefly as follows. Glass mixing bowls and battery jars can be used as aquaria, although excessive putrefaction often destroys the culture in the latter. The

glass cover of the aquarium should be propped up to leave a small air space; however, this is not absolutely necessary unless the cover becomes moist and imprisons a film of water between it and the side of the container.

Water from various sources, such as ponds, streams, taps, or rain, ranging in pH from 6.4 to 7.4, has been used in the aquaria, and even though no absolute failures were recorded which could be attributed to the water, pond water with an alkaline reaction was found to give the best results. When such water is used in a culture of clams, the pH decreases, and a good culture at its height, after the elapsed time of approximately three months, has a pH from somewhat below 5.2 to 5.9.

Assorted leaves from at least four species of oaks have been used in cultures; consequently, it is assumed that those available in any locality are likely to be satisfactory.

The duration of survival of a culture varies considerably and seems to be determined largely by the amount of food available for the clams. Some cultures have been retained for as long as eight months; at the end of this time they contained a few immature and adult clams. In the writer's experience the original supply of leaves, either in whole or in part, cannot be removed from a culture and replaced with new leaves without killing all the mollusks. Individual clams or successions of cultures may be retained, however, by transferring the clams to other aquaria prepared in accordance with the directions already given.

Observations on the rate of growth and the time necessary for the clams to reach maturity were made on a total of 104 clams distributed in 7 aquaria. The results of these observations prove that clams mature and begin to discharge young in 55 to 71 days, at which time their shells are 4.5 to 5.0 mm. long. After maturity has been reached the clams continue to grow and some of them attain a length of 9.0 mm.

Zoological Division, Bureau of Animal Industry
United States Department of Agriculture

DISTRIBUTIONAL VARIATION OF THE GANGLIONIC TRACHEAE IN THE LARVAE OF *ODONTOMYIA CINCTA* (DIPTERA) *

KIMBER CLEAVER KUSTER

INTRODUCTION

ACCORDING to the modern system of classification, *Odontomyia cincta* belongs to the first family (Stratiomyiidae) of orthorrhaphous Diptera. The adult flies are considered well up in the evolutionary scale with regard to specialized mouth parts, wing venation, and life history. There is great variation in the habits of the larvae in different genera of this family. Some live in the soil and have one pair of spiracles for each of seven abdominal segments, whereas others frequent open water of shallow pools and have one pair of functional spiracles in the entire abdomen. Here is a group of insects which has made marked advancement in the adult stage, but whose larvae range from pure terrestrial forms to the much-adapted aquatic type. Kuster (1934) gave experimental data on the ability of *O. cincta* larvae to remain submerged and to exchange respiratory gases in the tracheal system with dissolved gases in the surrounding water. Although these larvae may live several months in moist débris, they thrive best when they have access to water. In this paper the author wishes to call attention to the loss of certain ganglionic tracheae as evidence of possible evolutionary changes now actively in process.

The ganglionic mass in *O. cincta* larvae is concentrated in the mesothorax and the metathorax. From each of the thoracic segments a pair of tracheae lead from the lateral trunks to the three ganglia immediately behind the suboesophageal ganglion. The tracheae of each pair are connected by a short anastomosis. The number of ganglionic tracheae from the abdominal segments varies greatly. Leuzinger, Wiesmann, and Lehmann (1926) state that "in primitive fly larvae there is thus the typical number — 10 pairs of stigmata" and that "Ganglionic branches to the concentrated ganglion pass

* Contribution from the Department of Zoölogy, University of Michigan.

out of all 10 stigmata-bearing segments." Wahl (1900) sketches ten pairs of ganglionic tracheae in the larvae of *Eristalis tenax* L., seven of which are from the abdominal segments. The discovery of a wide variation in the number of ganglionic tracheae from the abodminal segments of *O. cincta* larvae has stimulated the author to make a morphological and statistical study of the distribution of these tracheae.

ACKNOWLEDGMENTS

The writer wishes to express his thanks and appreciation to the persons who generously assisted him with suggestions and criticisms. Special thanks are due to W. D. Baten, assistant professor of mathematics, University of Michigan, for determining the number of possible distributional patterns of ganglionic tracheae, and to M. J. Thompson, assistant professor of aëronautical engineering, University of Michigan, for applying Poiseuille's formulae to determine whether or not gas could pass through tracheae 17 to 35 microns in diameter.

COLLECTION AND TECHNIC

Larvae were collected in the moist débris of a dried-up woodland pool during late October and early November, 1933. Material from the natural habitat, with the addition of water, in an improvised terrarium proved to be a satisfactory place in which to keep the larvae throughout the winter and spring months.

Preparation of larvae for dissection involved (*a*) washing and scraping débris from the segmental folds, (*b*) submerging the specimens in 5 per cent hydrochloric acid to remove calcareous deposits on and in the integument, and (*c*) allowing them freedom to become thoroughly active in fresh water. Active swimming is associated with inflation of the tracheae. After larvae were anesthetized by chlorotone solution, which was injected into the thoracic region, they were stretched and pinned, dorsal side down, in a half-filled dish of paraffin and immediately covered with pure glycerine. Each segment was punctured to admit glycerine, which infiltrated through the tissue. In 18 to 48 hours the tissue became slightly firm, and the tracheae appeared silvery white. With the aid of a binocular microscope, fine-pointed curved forceps, and a small knife the entire ventral body wall was removed without disturbing the tracheae beneath. Imperfectly dissected larvae were discarded.

The ganglionic tracheae were traced from the points of origin on the lateral trunks to their termination in the ganglia. This was done for each abdominal segment on both the right and left sides. It was discovered that tracheae arising from the right lateral trunk never lead to left ganglia and vice versa. Neither did a trachea from a given abdominal segment lead to any but the corresponding ganglionic segment. Example: a trachea arising on the right side, in the 7th segment, terminated in the right side of the 7th abdominal ganglion. After these facts had been established, it was always possible to check the terminations of tracheae in the ganglia with their origins in the abdominal segments. The 8th abdominal ganglion was never observed to be supplied by tracheae from the lateral trunks; this ganglion was supplied by small branches from the tracheae to the 7th ganglion.

GANGLIONIC TRACHEAE IN DIPTEROUS LARVAE

It is a generally accepted fact that adult primitive insects and the larvae of primitive type have 8 pairs of abdominal spiracles and 8 ganglia in the 1st to 8th abdominal segments. Each pair of spiracles and the tracheae leading from them constitute a tracheal system. Any modification of this primitive arrangement indicates evolution of the tracheal and nervous systems. The 8 tracheal systems in the abdomen joined to form one complete system with those of the thorax and head. Likewise, the ganglia were connected in "chain" or "ladder" arrangement and extended caudad to the 8th abdominal segment. Modification of the nervous system in flies, as well as in other insects, consists in reduction of the number of ganglia, either by fusion or by loss, and concentration of the ganglionic mass in the mesothorax and metathorax of many of the larvae.

The larvae of *O. cincta* have only one pair of spiracles in the abdomen, and they are located inside the 8th segment. The only other pair of spiracles, which are not functional, are located in the dorsolateral margin of the prothorax. Although the author has not traced the development of these spiracles, he assumes that they had their origin in the segments mentioned. However that may be, this important fact remains, from a total of 10 pairs of spiracles in the larvae of primitive flies the number has been reduced to 2 pairs in *O. cincta*.

Respiratory gases enter and pass out through the posterior spiracles, which are gateways to the main tracheal trunks. The

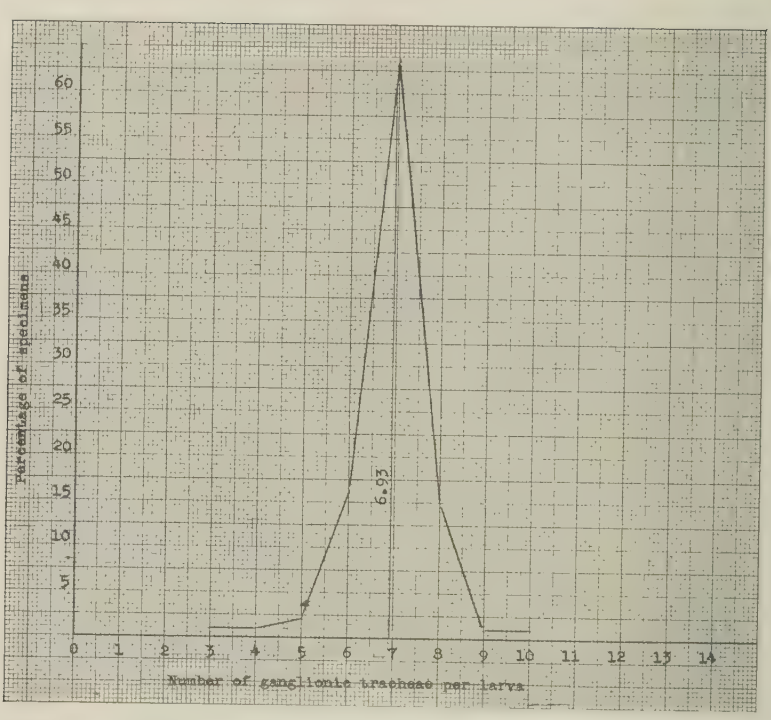

FIG. 32. Graph showing the distribution of ganglionic tracheae from one hundred larvae, 63 per cent of which had 7 ganglionic tracheae with a mean of 6.93. No larva had fewer than 3 or more than 10 tracheae.

lateral trunks are parallel and are connected to the main trunks by 10 spiracular trunks. The ganglionic tracheae extend from the lateral trunks to the ganglia. Wahl (1900) figures 7 pairs of ganglionic tracheae in the abdomen of larvae of *Eristalis tenax* L. One might expect to find at least the same number of tracheae in the larvae of *O. cincta*, but this is not the case.

DISTRIBUTION OF GANGLIONIC TRACHEAE IN *ODONTOMYIA CINCTA* LARVAE

One hundred specimens collected at random from the same habitat were dissected, and the distribution of ganglionic tracheae in the abdomen was plotted as shown in Table I. The number of tracheae

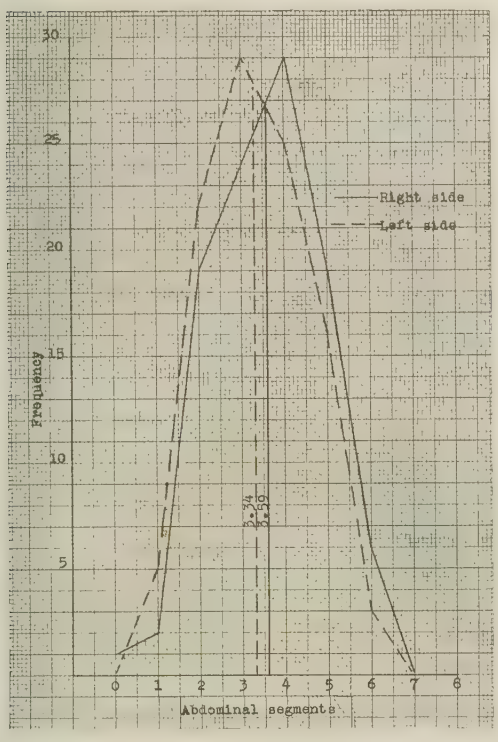

FIG. 33. A graphic comparison of the frequency of ganglionic tracheae on the right and left sides in the abdominal segments. The variation in the means is insignificant.

present varied as well as the pattern of distribution. The maximum number of these tracheae per larva was 10, the minimum 3, and the average 6.93. The average number for the right and left sides was 3.58 and 3.35 respectively. From Figures 32 and 33 it is apparent that there should be one ganglionic trachea per segment, and the difference between the averages of the right and left sides is insignificant. Sometimes tracheae occur in pairs. When this condition does exist it occurs most frequently in the 1st and 2d abdominal segments and least frequently in the 5th and 6th segments (Table II). The absence of both right and left tracheae in a segment occurs most

TABLE I

TRACHEAE LEADING FROM THE LATERAL TRUNKS TO THE GANGLIA IN THE LARVAE OF *ODONTOMYIA CINCTA*

R = right side of abdomen
L = left side of abdomen

\+ = trachea present
0 0 = tracheae absent on both sides

The numbers in the stub indicate the number of abdominal segments.

	1		2		3		4		5		6		7		8		9	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	+		+		+			+	+	+	+		+		+			+
2		+		+		+		+	+		+		+		+			+
3	+			+	+			+		+		+		+		+		+
4		+	+			+	+		+		0	0		+	+			+
5		+		+		+		+	+			+	+		+			+
6		+	+		+			+		+		+	+		+		+	
7		+	+		+		+			+		+		+		+	+	
	2+5=7		4+3=7		4+3=7		2+5=7		4+4=8		2+4=6		4+3=7		5+2=7		2+5=7	

	10		11		12		13		14		15		16		17		18	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	+			+		+	+	+	+			+	+			+		+
2	+		+		+			+	+	+		+	+		+		+	+
3		+		+		+		+	+			+	+		+		+	
4		+	+			+	+			+	+			+		+		+
5	+			+	+		+		+		+			+		+	+	
6		+	+		+			+		+		+	+			+	+	
7	0	0		+	+			+	+	+		+	+			+		+
	3+3=6		3+4=7		4+3=7		3+5=8		5+4=9		2+5=7		6+2=8		2+5=7		4+4=8	

	19		20		21		22		23		24		25		26		27	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1		+		+	+		+		+	+	+		+		+			+
2	+		+			+	+		+			+	+		+			+
3		+	0	0	+		+		+			+	0	0	+		+	
4	+			+	+		+			+	+			+		+	+	
5		+	+		+		+			+	+			+		+	+	
6		+	+			+		+	0	0		+		+	+			+
7	0	0	+		+		+			+	+		0	0		+		+
	2+4=6		4+2=6		5+2=7		6+1=7		3+4=7		4+3=7		2+3=5		4+3=7		3+4=7	

	28		29		30		31		32		33		34		35		36	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1		+	+		+		+			+	+	+		+		+		+
2	+	+		+	+		+			+	+		+		+			+
3	+			+		+		+		+		+	+		0	0		+
4	+			+	+		+		+			+	+		+			+
5	+		+			+	+		+			+	+		+			+
6	+			+		+	+		+		+		+		+		+	
7		+		+	+			+	0	0		+		+	+			+
	5+3=8		2+5=7		4+3=7		5+2=7		3+3=6		3+5=8		5+2=7		5+1=6		1+6=7	

TABLE I (*Continued*)

	37		38		39		40		41		42		43		44	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	+		+		+		+			+		+	+			+
2	+			+		+		+		+		+		+	+	
3	+	+	+		+		+			+		+		+	+	
4	+			+	+		+			+		+	+			+
5	+		+			+	+		+		+		+			+
6	+		+		+		+		+		+		+		+	
7		+	+		+			+	+		+		+		+	
	6+2=8		5+2=7		5+2=7		5+2=7		3+4=7		3+4=7		5+2=7		4+3=7	
	45		46		47		48		49		50		51		52	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1		+		+		+	+		+	+	+			+	+	
2		+	+		+			+	+		+			+	+	
3		+		+	+			+		+	+		+		+	
4		+	+			+		+	+			+	+		+	
5	+		+			+		+	+		+			+	+	
6		+	+			+	+			+		+	+			+
7	+			+		+	0	0	+			+		+		+
	2+5=7		4+3=7		2+5=7		2+4=6		5+3=8		4+3=7		3+4=7		5+2=7	
	53		54		55		56		57		58		59		60	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	+	+	+		+		+	+		+	+	+	+		+	
2		+	+		+		+		+		+		+			+
3	+			+		+	+		+		+			+		+
4		+	0	0		+		+		+	+			+		+
5	+			+	+			+	+		+			+		+
6		+	0	0		+		+		+		+	+		+	
7	+			+	+			+	+		+		+		+	
	4+4=8		2+3=5		4+3=7		3+5=8		4+3=7		6+2=8		4+3=7		3+4=7	
	61		62		63		64		65		66		67		68	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1		+		+	+		+		+			+		+		+
2		+	+		+		+			+		+	+			+
3	+		+		+		+			+		+	+			+
4	+		+		+		+	+	+			+		+		+
5		+		+		+		+	+		+		+		+	
6	+		+			+	+		+		+			+		+
7		+	0	0	+		+			+	+			+	+	
	3+4=7		4+2=6		5+2=7		6+2=8		4+3=7		3+4=7		3+4=7		2+5=7	

TABLE I (*Concluded*)

	69		70		71		72		73		74		75		76	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	+		+			+		+		+	+			+	+	+
2		+	+			+		+		+	+			+		+
3	+		+			+	+			+		+	+			+
4	+			+		+		+		+		+	+		+	
5	+		+		0	0	+		+		+		+		+	
6	+			+		+	+		+		+		+			+
7	+					+		+	+			+	0	0		+
	6+1=7		5+2=7		0+6=6		3+4=7		3+4=7		4+3=7		4+2=6		3+5=8	
	77		78		79		80		81		82		83		84	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1		+		+	+		+		+	+	+			+	+	
2	+		+			+		+	+		+			+	+	
3		+		+		+	+			+		+	0	0	0	0
4	+		+		+		+		0	0	+		+		+	
5		+	+		+			+		+		+	+			+
6	+			+		+		+	0	0		+		+		+
7	+			+	+			+		+	+			+	+	
	4+3=7		3+4=7		4+3=7		3+4=7		2+4=6		4+3=7		2+4=6		4+2=6	
	85		86		87		88		89		90		91		92	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	+	+	+	+	+		+		+		+		0	0	+	
2	+		+	+	+		+		+		+		0	0	+	
3		+	+		+		+			+		+	+		0	0
4		+		+		+		+	+		+		0	0		+
5	+			+		+	+			+	+			+	+	
6		+	+		+		+			+	+		0	0	0	0
7		+	+	+		+		+	+			+	+		0	0
	3+5=8		5+5=10		4+3=7		5+2=7		4+3=7		5+2=7		2+1=3		3+1=4	
	93		94		95		96		97		98		99		100	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	+		+	+		+		+		+	+			+	+	
2		+	+			+		+		+	+		+			+
3		+		+	+		0	0	+		+		+			+
4	+			+	+			+		+	+		+		0	0
5		+	+		+		+			+		+	+			+
6		+	+			+		+		+		+		+	+	
7		+	+			+	+			+		+	0	0	+	
	2+5=7		5+3=8		3+4=7		2+4=6		1+6=7		4+3=7		4+2=6		3+3=6	

frequently in the 7th segment. Thirteen per cent of the specimens had right and left tracheae in the 1st segment and none in the 5th, 6th, and 8th. With the exception of 2 per cent of the specimens that have right and left in the 7th segment, the tendency for this condition is prevalent in the anterior portion of the abdomen. On the other hand, absence of both a right and a left trachea is most frequent in the posterior portion of the abdomen. Although this condition occurs in all segments, the highest percentages happen to be in the 7th and 8th segments. From these data it is suggested that tracheae are being lost from the posterior end of the larva forward. Theoretically, there might be 16 ganglionic tracheae in the abdomen of one larva, but the probability is nil. Sixty-three per cent of the specimens had 7 tracheae, 16 per cent had 6, and 15 per cent had 8. The remaining 6 per cent had 3, 4, 5, 9, and 10 tracheae (Fig. 32).

TABLE II

Segments with Right and Left Tracheae Compared with Those Having neither Right nor Left Tracheae

Abdominal segment	Right and left tracheae present	Neither right nor left tracheae present
	Percentage	Percentage
1	13	1
2	4	1
3	1	7
4	1	5
5	0	1
6	0	5
7	2	9
8	0	100

Since other fly larvae actually do have 14 of these tracheae, it is assumed that those of *O. cincta* might have the same maximum number. It may also be assumed that, since the minimum number found was 3, these larvae might lose all the ganglionic tracheae in the abdomen. One might deduce from these assumptions that the number of tracheae may range from 0 to 14 if a sufficient number of specimens is examined. According to the law of averages, a specimen with no tracheae and one with 14 would occur once among 16,384. It is doubtful whether or not a larva could survive with fewer than 3 tracheae to the abdominal ganglia. From the nature of the curve

(Fig. 32) it would seem highly improbable that specimens with 11, 12, or 14 tracheae will occur.

TABLE III

Distribution Patterns of Ganglionic Tracheae Which Occurred More than Once in 100 Random Specimens

Specimen No.		7 74		8 31 90		13 76		16 64		17 47		24 79	
Abdominal segments		R	L	R	L	R	L	R	L	R	L	R	L
	1	+		+		+	+	+			+	+	
	2	+		+			+	+		+			+
	3		+		+		+	+		+			+
	4		+	+		+		+	+		+	+	
	5	+		+		+			+		+	+	
	6	+		+			+	+			+		+
	7		+		+		+	+			+	+	
		4 + 3 = 7		5 + 2 = 7		3 + 5 = 8		6 + 2 = 8		2 + 5 = 7		4 + 3 = 7	

Specimen No.		26 87		30 82 89		34 40		41 42 66 73		45 68		51 61	
Abdominal segments		R	L	R	L	R	L	R	L	R	L	R	L
	1	+		+		+			+		+		+
	2	+		+			+		+		+		+
	3	+			+	+			+		+	+	
	4		+	+		+			+		+	+	
	5		+		+	+		+		+			+
	6	+			+	+		+			+	+	
	7		+	+			+	+		+			+
		4 + 3 = 7		4 + 3 = 7		5 + 2 = 7		3 + 4 = 7		2 + 5 = 7		3 + 4 = 7	

It is apparent from Table I that these tracheae may be distributed in a great many ways. A larva with 7 tracheae also has 7 vacant places. Assuming that one trachea is like every other one and that the 7 may occur in any possible combination with the 7 blank positions, mathematically there are 3,432 possibilities. The total number of possibilities for the observed range of 3 to 10 is 15,808. With this large number of possible patterns of tracheae it would seem highly improbable that from 100 specimens 2 would be found with the same distributional pattern of ganglionic tracheae. The results

of a check are given in Table III. Specimens 41, 42, 66, and 73 had the same pattern. Specimens 30, 82, and 89 were alike, as well as a number of others. According to the law of chance, only once among 15,808 specimens would 2 be expected to have identical distribution of tracheae. To find 4 specimens among 100 larvae having the same pattern is considered significant evidence that a definite pattern of distribution is being maintained during the process of losing tracheae. Only 72 per cent of the specimens had individual patterns. The other 28 per cent consisted of 12 patterns of distribution. All the latter had 7 or more ganglionic tracheae. Four specimens had tracheae in pairs, and no segment was without a trachea. The prevalent tendency is for tracheae to occur in series, first on one side and then on the other side. However, specimen 11 is an example of zigzag arrangement from left to right. Specimen 71 had all the tracheae on the left side. A full complement of 7 on the right side is reported by Kuster (1934) in specimen 2, Table II, page 634.

These tracheae range in diameter from 17 to 35 microns and may have a maximum length of 18 mm. There has been a question whether or not tubes of this size could serve for the passing of respiratory gases to and from the abdominal ganglia. Poiseuille (1842) demonstrated that water under pressure would pass through glass tubes smaller than 17 microns in diameter. Air which has a coefficient of viscosity one fiftieth of that of water would pass through the same tube 50 times more rapidly, at the same pressure. Since blood courses readily through the capillaries of man, although they may be less than 8 microns in diameter, it is not speculation to assume that an ample supply of respiratory gases passes to the ganglia through these small tubes. Gas has been seen to escape from a severed ganglionic trachea of a specimen submerged in glycerine.

Usually segments without tracheae are between segments in which tracheae occur. It is seldom, therefore, that two adjacent ganglia are without a direct supply of oxygen. A ganglion without an individual trachea must depend for its oxygen supply upon diffusion of oxygen from the surrounding tissue and from the blood. Specimens 91 and 92 are examples in which two adjacent segments lack tracheae and in which the corresponding ganglia are without an independent oxygen supply. In specimen 92 the 6th, 7th, and 8th segments and ganglia are without tracheae. The pattern of tracheal arrangement in these two specimens is unusual as compared with that of specimen

number 41. It seems reasonable to suspect that larvae with fewer than three abdominal ganglionic tracheae would not receive an adequate supply of oxygen upon which to survive. A larger series of specimens may furnish data which would disprove this conjecture, but according to Figure 32 the probability is exceedingly remote.

SUMMARY

1. The number of ganglionic tracheae in the larvae of *Odontomyia cincta* ranges from a minimum of 3 to a maximum of 10 in 100 random specimens from the same habitat.

2. In the larvae of *O. cincta* the number of tracheae has been reduced from 14 in primitive adult insects and larvae of primitive type to an average of 7, one for each from the 1st to the 7th abdominal segments.

3. The reduction is most prevalent at the posterior end.

4. There is a definite pattern of arrangement of ganglionic tracheae in which the tendency is for them to occur in series of two or more, rather than zigzag from one side to the other.

5. It is concluded that the reduction in number of tracheae is fortuitous and not due to possible physical inability to function.

6. A segment in which a ganglionic trachea originates may be determined by the ganglion in which the trachea terminates.

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LITERATURE CITED

Kuster, Kimber C. 1934. A Study of the General Biology, Morphology of the Respiratory System, and Respiration of Certain Aquatic *Stratiomyia* and *Odontomyia* Larvae (Diptera). Pap. Mich. Acad. Sci., Arts and Letters, 19 (1933) : 605–658.

Leuzinger, H., Wiesmann, R., and Lehmann, F. E. 1926. Zur Kenntnis der Anatomie und Entwicklungsgeschichte der Stabheuschrecke Carausius morosus Br. IV. Über die Entwicklung des Tracheensystems, nebst Beitragen zur vergleichenden Morphologie des Insekten-Tracheensystems. Gustav Fischer, Jena.

Poiseuille. 1842. Recherches expérimentales sur le mouvement des liquides dans les tubes de très-petits diamètres. Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences, Paris.

Wahl, Bruno. 1900. Über das Tracheensystem und die Imaginalscheiben der Larve von *Eristalis tenax* L. Arbeiten aus dem Zoologischen Institut der Universität Wien u. d. Zoologischen Station in Triest, 12 : 45–98, 5 pls.

THE JAW-TAG METHOD OF MARKING FISH*

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THE tagging or the marking of fish to determine life history, growth rate, migrations, and other facts is a well-established practice in scientific fisheries biology. Marking, the process of cleanly excising one or more fins, is suitable for mass experimentation only. Tagging, the attaching of a serial number to the fish by one of several means, yields much more valuable information on the movements and the growth rates of fish so treated, since by this means it is possible to trace the history of the individual fish.

Previous investigators have experimented with various kinds of tags on numerous species of both marine and fresh-water fish. Out of this past work three kinds of tags have evolved. The earliest one is the "button" type, which consists of two vulcanite or hard rubber disks connected by silver wire. The wire is passed through the flesh of the fish and holds the buttons on each side of the body. It is also applicable to the operculum. Another type, one used predominantly in North America, is the "metal strap" tag, or "clip" tag. This tag is a metal clip provided with a simple locking device operated by a special pair of pliers. It can be attached to any of the fins, to the caudal peduncle, or to the gill cover. The most recent development is the "belly" tag, a thin celluloid strip, which is inserted from the exterior through an incision made in the side of the fish. A feature common to all types is the printing or stamping on each of a serial number and a forwarding address.

The earlier tagging work conducted for the Michigan Department of Conservation by the Institute for Fisheries Research made use of the strap tag. Points of application were the caudal peduncle, gill cover, and occasionally the dorsal fin. Returns from this work were meager; only two and seventy-one hundredths (2.71) per cent of some twenty thousand fish were recovered, and most of the returns were limited to only four of ten species of fish tagged.

* Contribution from the Institute for Fisheries Research, Department of Conservation, State of Michigan.

During 1932 and 1933, in the course of an attempt to develop a more satisfactory tagging technique, Dr. John R. Greeley demonstrated with fingerling trout at the State Hatchery, Harrietta, Michigan, the feasibility of ringing the lower jaw with the strap tag, and showed it to be superior to attaching tags to the dorsal fin, the caudal peduncle, or the gill cover.[1] In order to test the applicability of the jaw-tag method to larger fish Dr. Greeley and the writer tagged sixty-five rainbow trout in the fall of 1933 at the Federal Hatchery, Northville, Michigan. The size range of these fish was from eight to twelve inches, total length. When these fish were examined one year later (November 1, 1934), thirty-two were found to have held their tags; all were in good health. Since hatchery conditions at that date made it impossible to inspect the entire stock of trout in the ponds, even more than thirty-two trout may have held their tags. It may be concluded, then, that at least 50 per cent of the tagged trout held their tags over a period of one year. Observations revealed that the smallest tags, when used on these larger rainbow trout, did not leave the jawbone enough room in which to grow, and as a result 66 per cent (ten fish) of the trout with the small tags forced them loose and lost them. Trout over nine inches long should be tagged with No. 3 tags; those less than nine inches carry the fingerling size very well. The results of the experiment seemed to point out that, when a tag of the proper size was applied to the jaw, it would be carried by the trout over relatively long periods of time.

In view of these experiments the jaw-tag method has been adopted by the Institute for Fisheries Research for use in all tagging work on soft-rayed fishes. The clip tag (in three different sizes) is the type used, and its application to the fish is a relatively simple operation. A small slit is made with a scalpel under and inside the mandible. The short end of the tag is then inserted through the aperture and clamped through the lockhole on the opposite end of the tag. This projecting short piece is pinched down firmly with jeweler's pliers, and thus the tag is locked. To allow for growth of the jaw, the resulting elongate oval is spread to an approximately circular shape by pressure exerted from both ends of the oval by means of the pliers.

The jaw-tag method of marking fish is in use at present in an investigation of movements and growth rate of the brook and the brown

[1] Dr. Greeley's findings are contained in an unpublished report of the Institute for Fisheries Research.

trout on the North Branch of the Au Sable River. Between July 25 and September 27, 1934, 1,061 brook trout and 36 brown trout were marked by this method. Of the 1,097 trout so tagged, 490 brook trout, or 46 per cent, and 7 brown trout, or 19 per cent, were recovered. Of the 1,061 brook trout tagged, 27 per cent were recovered and remeasured from one to five times. These repeated recoveries within five months have provided rather accurate knowledge of their migrations and growth rates. The comparatively high percentage of returns is attributed to two factors: (1) a better location of the tag on the fish, and (2) repeated seining in and around points where fish were tagged — a more efficient and dependable method of obtaining recoveries than that offered by fishermen's returns. The publication of results on migration and growth rates will be deferred pending the addition of next summer's data.

It is the hope of the Institute for Fisheries Research to be able to continue this interesting study, and to develop the general technique of tagging to a point where it will be a more valuable aid to the Conservation Department in the scientific attack on its many fisheries problems.

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AN INVESTIGATION OF THE BURROWING INNER-BEACH INSECTS OF SOME FRESH-WATER LAKES *

J. K. GWYNN SILVEY

EXPOSED sandy beaches of northern lakes often possess three more or less parallel zones which have a certain distinctness, depending somewhat upon local conditions. It is possible to distinguish three zones: (1) inner beach; (2) middle beach; (3) outer beach. The *inner beach* extends from the edge of the water up the slope to the place where the surface sand is no longer saturated with water and where the first traces of drying occur. This zone is relatively narrow and somewhat exposed to the occasional wash of the more gentle waves of calm weather. The *middle beach* occupies the region just shoreward of the inner beach. It is subject to wave contact only during ordinary rough water. In calm weather this zone has a dry surface, although it contains water at deeper levels. The *outer beach* extends from the middle beach to the landward limit of the beach proper. Waves reach it only during violent storms. In the summer it is usually dry to some depth and subject to some shifting of the sand by winds. It may support a few beach plants.

These zones, where produced in typical form, are commonly kept free of the coarser débris, although some of the finer detritus becomes mixed with the sand. During calm weather drifts of organic matter may occur near the water line.

In many inland lakes of the Great Lakes region, and probably elsewhere, the inner beach, when developed, possesses a unique assemblage of burrowing insects which has virtually never been studied. The investigation upon which this paper is based was primarily an ecological one, but attention was also given to life histories and taxonomic relationships.

* Contribution from the University of Michigan Biological Station and from the Department of Zoölogy, University of Michigan.

Consideration of the burrowing inner-beach insects from an ecological standpoint has heretofore been neglected, and there is almost no literature on the subject. There are but a few brief reports of mud-burrowing forms, such as that of Claycomb (1919), with figures of life-history stages not unlike those of sand-burrowing forms. Klunzinger (1906) and Williams and Hungerford (1911) also described life-history features of certain heterocerids. Andrews (1921) mentioned the occurrence of omophronids, carabids, and heterocerids under débris on beaches. Dury (1902) showed that certain families of Coleoptera include species that burrow, and he contributed a few notes of biological interest. Wickham (1903) also showed that some members of the families dealt with later in this paper are burrowers. No taxonomic references to the larval stages of the species involved in this work are known to the writer.

This work was done at the University of Michigan Biological Station on Douglas Lake, Cheboygan County, Michigan. The shores of Douglas Lake are very suitable for studying the burrowing forms of the inner beach. Also in the vicinity of Douglas Lake there are several lakes whose beaches support such an insect population.

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Methods

All the species studied make runways or burrows just beneath the surface of the inner-beach sand. Often these burrows attain great length, and at other times are just long enough to cover the hidden insect. Wide sand-bar and sand-spit inner beaches generally support the larger number of burrowers. These beaches are saturated with water, so that tramping lightly on the sand forces the water to the surface and thus destroys the burrows and buoys the insects to the surface. In this manner rapid collecting could

be carried on. Since most of the adult burrowers are good fliers, fast collecting was necessitated if many were to be captured. A slower method of collection was that of digging the insects out of the burrows. A bent dissecting needle or a similar instrument was employed to remove the top of the burrow and expose the animal. At night the writer collected many individuals by using a light to attract them, but this method is unsuccessful for those that do not fly.

For mass collection a soil sieve with a mesh one-sixteenth of an inch was used. A small shovel or a trowel was employed to take up the sand containing insect burrows and to place it in the sieve. The sieve was then carried out into the lake where the water was about twelve inches deep, and by rotating the partly submerged sieve, first in one direction and then in the other, most of the sand was removed. The sieve was then placed in water about three inches deep. Overflow at the rim was avoided, so that the insects were floated on the surface and easily collected.

Fauna

The insects occurring on the inner beach fall into two categories: (1) those that make their own burrows and live in them most of the time; and (2) those that are not fossorial, but may occupy the burrows made by other species. The former group has been referred to as the true burrowers; the latter, as visitors. These designations indicate more or less the true relation of the insects to the inner beach, as will be shown later. The lists of species given below do not include all the miscellaneous beetles that have been collected from time to time on inner beaches, but give only those which actually belong to this assemblage.

1. TRUE BURROWERS

Dyschirius nigripes Lec.
Dyschirius longulus Lec.
Dyschirius terminatus Lec.
Dyschirius sphaericollis Say
Bembidion confusum Hayw.
Agonoderus pallipes (Fab.)
Homophron americanum (Dej.)
Homophron tessellatum (Say)
Heterocerus auromicans Kies.
Bledius sp.

2. VISITORS

Elaphrus ruscarius Say
Bembidion littorale (Oliv.)
Bembidion transversale Dej.
Bembidion patruele Dej.
Bembidion intermedium Kby.
Bembidion mackinacensis Hatch
Calathus gregarius Dej.
Agonum errans (Say)

Agonum octopunctatus (Fab.)
Chlaenius sp.
Anadaptus discoideus (Dej.)
Hydroporus undatus Say
Chaetarthria sp. Steph.
Stenus stygicus Say
Stenus sp.
Gastrolobium bicolor (Grav.)
Philonthus confertus Lec.
Myllaena intermedia Er.
Lucidota nigricans (Say)
Mordellistena cervicalis Lec.

Distribution

In the region studied burrowing insects occur with greater frequency on more protected portions of the inner beach. Sand-spits are generally covered with runways of these insects. Sand-bars have many burrows on parts that are rather level and not exposed to wave action. At all times the narrow inner beach accommodates few burrowing beetles but, when present, the burrows are nearer the middle beach. During high waves the zone of burrowing may shift toward the middle beach; quiet surface water may produce the opposite effect.

TRUE BURROWERS

Dyschirius nigripes. — Adults on outer portion of inner beach; mostly in very protected sand-spit regions formed by slowly receding waters; about three inches beneath surface sand; most often in very small tunnels. Eggs, larvae, and pupae not found.

Dyschirius longulus. — Resembles *D. nigripes* in appearance and habitat; differs in its reddish color and wider distribution.

Dyschirius terminatus. — Rare in northern Michigan; collected only on inner side of water-saturated barrier beach bars.

Dyschirius sphaericollis. — Collected on all three types of sandy inner beach; scattered widely on narrow inner beaches, generally on side nearest lake; many on lakeward sides of sand-spits; burrows only fraction of inch beneath surface of sand. Eggs in runways; each egg encased in small sand capsule. First instar larvae producing small tunnels just large enough to permit movement. Larval burrows more numerous on sand-spits; almost imperceptible because of small size and drying of surface sand. Pupae in widened final parts of larval burrows.

Bembidion confusum. — Frequents sand-spits and barrier sand-bars; on those narrow inner beaches in close proximity to other types of habitat. Large burrows infrequent. Individuals active on the surface of the inner-beach sand. Eggs in shallow burrows on

inner beach. Larval runways just large enough to accommodate active movement. Pupae in small cell excavated in burrow.

Agonoderus pallipes. — Rare at times, common at others; adults on the lakeward side of small sand-spits or newly formed sand-bars.

Homophron americanum. — On the older parts of sand-spits and sand-bars; burrows not obvious because of the drying of surface sand; about one inch beneath surface or wherever moisture becomes sufficient to hold sand grains together; found only by recognition of the type of environment. Eggs in burrows; encased in small protective sand capsules. Larval burrows on damper parts of inner beach, producing characteristic runways just beneath surface. Pupae in enlarged part of burrows.

Homophron tessellatum. — Abundant on newly formed sand-spits protected in small coves or harbors; common on narrow inner beaches, but never in large groups. Newly made burrows obvious on all kinds of inner beaches; not permanent. About three inches below surface of sand on old inner beach. Eggs in sand, generally in burrows or just underneath damp sand; enclosed in small protective sand capsules, open at one side. Larval burrows just under surface sand; obvious from above and bizarre in shape. Larvae more numerous than other immature forms on inner beach, or sometimes apparently so, because of their large tunnels; in all types of inner beach; sometimes in rather large aggregations. Pupae in enlarged part of burrows.

Heterocerus auromicans. — Common on wet portions of sand-spits, old barrier sand-bars, and wide inner beaches formed by receding lake waters as flat expanses of very wet sand. Eggs, appearing as very small clusters of whitish balls, in deserted burrows about one inch beneath surface. Larval burrows in the same situation. Pupae in enlarged part of burrows.

VISITORS

On a wide expanse of evenly sloping inner beach partly covered with Equisetum one will find *Elaphrus ruscarius, Agonum errans, A. octopunctatus,* and *Calathus gregarius.* These carabids dart in and out among the vegetation, but seldom enter burrows formed by other species. As the beach narrows and the vegetation disappears one finds very different species. Visitors living on this narrow

inner beach are numerous, but the number of species is small. Among them are *Bembidion transversale*, *B. patruele*, and *B. intermedium*.

Barrier sand-bars support various visiting species, which are especially numerous after the bar has gained connection with the rest of the inner beach. In this group are *Bembidion littorale*, *B. intermedium*, *B. patruele*, *Agonum errans*, *Stenus stygicus*, *Lucidota nigricans*, and *Philonthus confertus*. Sand-spits of all ages have a varied population of visitors, among which are *Bembidion littorale*, *B. patruele*, *B. intermedium*, *B. mackinacensis*, *Agonum errans*, *Hydroporus undatus*, *Stenus stygicus*, *Gastrolobium bicolor*, *Philonthus confertus*, *Myllaena intermedia*, and *Mordellistena cervicalis*. This list does not include all species collected in the inner-beach vicinity.

Quantitative and Qualitative Distribution

Special surveys were made around the inner beaches of Douglas Lake in order to determine the quantitative and qualitative distribution of the burrowing species. One hundred stations were marked around the shores on different types of sandy inner beaches. Uninhabitable parts of the beach were given no consideration. The stations were established one hundred paces apart, chosen at random on the inner beach. A wooden frame, one foot square, was used to mark a certain area on the beach, and all the sand excavated to a depth of six inches was placed in a sieve of appropriate mesh. The burrowing and the visiting insects in this area were collected by this method, as previously described.

Table I gives the actual number of organisms taken on one hundred square feet of sandy inner beach during June and July, 1929 30. It should be noted that the insects were collected from all types of inner beach and at particular stations.

The second survey was made in late August and early September in the summers of 1929 and 1930. The data secured (Table I) show that there had been a decrease in the quantity and the quality of some of the adult forms. The numbers of *B. confusum*, *S. stygicus*, and *H. tessellatum* had increased slightly over those found in the previous survey.

Distribution on Different Lakes

An examination of the inner beaches on other lakes in the Douglas Lake region revealed the presence of burrowing species. Not

all beaches proved equally productive. A few larvae of *H. tessellatum* were secured at various places on the shores of Burt Lake. Other true burrowers were absent. Visitors occurred in large groups, although the variety of species was small; *B. patruele* and *B. intermedium* were the only species collected. However, not all the beach region on this lake was examined. Sand-spit and sand-bar formations on Carp Lake were numerous enough to provide a suitable habitat for burrowing beetles. The true burrowers found were *H. tessellatum*, *H. auromicans*, *B. confusum*, *H. americanum*, and *D. sphaericollis*. *B. littorale*, *B. intermedium*, and *B. patruele* were among the visiting species.

TABLE I

Quantitative and Qualitative Distribution of Burrowing Insects on Beaches of Douglas Lake

All values represent averages.

Species	Number of insects per 100 square feet 1929 and 1930	
	June–July	Aug.–Sept.
H. auromicans	165	85
Carabid larvae	31	38
B. confusum	9	14
D. sphaericollis	8	3
B. intermedium	6	3
H. tessellatum	5	5
H. americanum	4	2
B. littorale	4	..
D. longulus	2	1
A. pallipes	2	1
D. nigripes	1	1
D. terminatus	1	..
A. errans	1	1
S. stygicus	1	4

Few bog lakes have an exposed shore line sufficiently large to provide a sandy beach. Vincent Lake is an exception, since it has a small amount of beach on one side. Only one burrowing larva was found, the immature form of *B. littorale*. The adults of this species were collected on the same beach, although they do not burrow. No true burrowing adults were found.

The beaches of Munro Lake were prolific in burrowing insects. There were no sand-spits in the early part of the summer, but be-

fore it was half over many had formed. In addition, barrier sand-bars were scattered up and down the shore lines for a quarter of a mile or more. These species always found to be very prevalent were *H. tessellatum*, *H. americanum*, *H. auromicans*, *B. confusum*, and *D. sphaericollis*. Not only were the adults very numerous, but the beaches, because of their stability, provided a very good place for the immature stages of all the species mentioned above. In addition to the true burrowing species, there were numerous visitors, though not representing many species. Visiting species were: *B. intermedium*, *B. patruele*, *A. errans*, *B. littorale*, and *Philonthus confertus*. A few of the rarer burrowers, such as *D. nigripes*, *D. longulus*, and *A. pallipes*, were taken infrequently. The large number of barrier beach bars and sand-spits made Munro Lake as productive as Douglas Lake, although the former had less expanse of inner beach.

Physical Features of Environment

wind action

The influence of wind action on the distribution of burrowing insects, which is largely secondary, is through its effect upon the beaches. It seems to play a primary rôle only when prolonged or extremely high; at such times it forcibly scatters the immature and the adult insects. Wind action may also partly control the food supply, the stability of beaches, and the water content of surface sand.

wave action

Burrowers on older sand-spits and barrier sand-bars are not greatly endangered by high waves, but, in instances of freshly formed sand-spits and sand-bars, the highest waves may lash well up the surface. If this portion of the surface is occupied by burrowers, their runways are destroyed and the inhabitants carried on the water. Such species as *H. auromicans* and *B. confusum* are able to fly directly from the surface, but others that are unable to fly swim back to the sandy beach. On reaching the inner beach the insects crawl to a more protected place and make other burrows. Some immature stages are often carried out into the lake and never return; others perform in the same way as the adults in regaining the old habitat.

Wave action on the narrow inner beach is more effective on the

inhabitants than it is on other types of beaches. During excessive wave action the entire inner beach is washed by the waters from the lake, so that if burrowers are present they are washed out. When disturbed, they act as has been previously described, except that they may at times burrow in the middle beach until the waves have abated. Thus wave action causes occupancy of the narrow inner beach to be more hazardous than occupancy of the other two types of habitat.

MOLAR AGENTS

Molar action is here caused by pebbles, stones, and larger sand grains in the beach rubbing together and by the impacts of finer sand grains carried in suspension by the moving water. This effect is produced through the action of winds and waves. The narrow inner beach, because of its situation and formation, has considerable molar action which, when severe, prevents the burrowers from producing runways of any description, and thus makes occupancy almost impossible. Molar agents are not continually active, being virtually absent in times of calm. These statements apply not only to the narrow inner beach, but also to the barrier sand-bars and sand-spits.

WATER CONTENT

The narrow inner beach, because of compactness of the sand due to wave action, does not have an excessive amount of water. When the water content is low, it is difficult for the small burrowing insects to tunnel beneath the surface of the sand; hence they are either absent or occur in limited numbers.

The barrier sand-bars and sand-spits vary in water content according to their age and formation. In the barrier sand-bars of recent development the water content is high, since the surface of the bar is just above the surface of the water and since the sand composing it is not packed. As the bar grows older, more sand is added to its surface, producing a formation that rises higher above the water level. If wave action is present, even in a small degree, the sand is gradually packed. This action continues until the sand-bar possesses a surface that is dry, except for the edges which are in the water. These gradual changes account, in part, for the variations that are noted in the insect population.

Sand-spits always possess high water content. In new sand-

spits the percentage of water is higher than at other times, since their surfaces are just above the water line. As the sand-spit begins to age, the water content becomes reduced in the surface sand. The amount of water in the lower sand layers, however, remains constant. Those insects regularly found in this environment have all the water which they need.

Chemical Features of Environment

Chemical analyses were made of the water contained in the sand of the inner beach and, as might be expected, it possessed essentially the same chemical features as did the surface lake water. Though some decomposition of the organic matter takes place in the inner beach, the continuity of the contained water with the surface water of the lake and the gentle lapping of the wavelets in calm weather probably keep all accumulations of decomposition products leveled out. Since the chemical features were essentially uniform, the detailed data of the chemical analyses are omitted here.

Biological Features of the Environment

vegetation

The effect that vegetation plays in the distribution of these insects is slight. Most of the plants consist of small herbs and shrubs, with occasional patches of grass and larger bushes. The narrow inner beach seldom supports plants of any kind, since the physical agents prevent their continued existence. Vegetation acts on the burrowing insects only when it becomes dense enough to hinder or inhibit their activities. On the other hand, vegetation may exert an indirect effect upon those insects dependent upon sand-bars and sand-spits. Barrier sand-bars, when first formed, appear to be rather temporary structures. However, roots of rapidly growing vegetation aid in giving the bar a permanent basis. Also, sand-spits are often kept fixed by vegetation.

food supply

Plankton washed upon the inner beach sand serves as food for the burrowing insects. In addition to the plankton there are other microörganisms which seem to be regular residents of the inner-beach sand. This latter group is still little known. Also, nothing is yet known concerning the extent to which they serve as food for the

burrowing insects. Therefore, all the discussion in this section deals with the plankton.

The narrow inner beach seldom supports a large amount of plankton material. In certain instances plankton "drifts" cause portions of the inner beach to be heavily infiltrated with plankters. Plankton drifts are usually caused by onshore winds producing onshore waves of a certain velocity. These drifts are temporary, since a slight change either in direction or in velocity of the wind distributes the drifted plankton back into the open lake.

Quantitative counts of microörganisms in the three types of inhabited beaches showed that the narrow inner beach maintained the smallest number; the barrier sand-bars were next in quantity; and the sand-spits maintained the largest number. It was found that the distribution of the burrowing insects depends, to some extent, upon the distribution and the quantity of these food materials.

Burrows

These insects produce burrows so characteristic that the species making them can be identified by their size and form, but experience is necessary to enable one to recognize the different kinds of burrows since, at first sight, they appear quite similar. The adults of a species may produce one type of burrow, but the larvae of the same species may make an entirely different sort. Larvae of different species have different types of burrows.

Larval burrows vary in size according to the larval instar, but the form of the burrow does not change, no matter which instar produces it. Burrows produced by adults are, at most times, of a constant size and shape peculiar to the species of beetle inhabiting it.

KEY FOR THE IDENTIFICATION OF BURROWS

I. Nonbranching burrows
  A. Burrow extending wholly or in part beneath surface stratum of sand
    1. No obvious surface connection; burrow at least one inch below surface of sand
      a. Simple; horizontal; straight; diameter not exceeding 2 mm. (Pl. LXV, Fig. 29) ..... *D. nigripes* adults
      b. Simple; inclined slightly toward vertical; almost straight; diameter not exceeding 3 mm. (Pl. LXV, Fig. 30) *D. longulus* adults

2. Obvious surface connection present; course of burrow inclined more or less downward
   a. Course of burrow in two portions: (*a*) upper downward sloping section, followed by (*b*) horizontal extension (Pl. LXV, Fig. 31) ..... *A. pallipes* adults
   b. Course of burrow not in two distinct portions
      (1) Course of burrow inclined
         (a) Entire course of burrow with slight vertical inclination; depth, 4–5 cm. (Pl. LXV, Figs. 32–33) *H. tessellatum* adults
         (b) Entire course with great vertical inclination: depth, 1–3 cm. (Pl. LXV, Fig. 34)..... *B. confusum* adults
      (2) Course of burrow essentially horizontal; shallow
         (a) Course irregular; enlargements at intervals (Pl. LXV, Figs. 35–36) ..... *H. americanum* adults
         (b) Course irregular, but diameter constant (Pl. LXVI, Fig. 37) ..... *B. confusum* larvae

B. Burrows in surface layer
   1. Course of burrow irregular; surface perforations in burrow (Pl. LXVI, Fig. 38)..... *D. sphaericollis* adults
   2. Course of burrow straight; surface perforations absent (Pl. LXVI, Fig. 39) ..... *D. sphaericollis* larvae

II. Branching burrows; near surface
   A. Burrows with main tunnel
      1. Lateral burrows branching off from main burrow; diameter constant
         a. Branches rebranching (Pl. LXVI, Fig. 40) .. *H. tessellatum* larvae
         b. Branches simple (Pl. LXVI, Fig. 41)..... *H. americanum* larvae
      2. Lateral burrows branching off from main burrow always smaller in diameter (Pl. LXVI, Fig. 42)..... *H. auromicans* larvae
   B. Burrows without main tunnel, burrows branching; course extremely tortuous (Pl. LXVI, Fig. 43) ..... *H. auromicans* adults

Descriptions of Burrows

D. nigripes adult

Burrows about 7.5 cm. under surface; unbranched; slightly vertical course, later turning horizontal. Direction straight; diameter not over 2 mm. Found ordinarily in older portions of sand-bars, sometimes in portions of sand-spits unaffected by seasonal changes. Length, 10–30 cm.

D. longulus adult

Burrows 2.5–7.5 cm. beneath surface; unbranched; entire course inclined slightly from surface to depth of 7.5 cm. Diameter, 2–3 mm., seldom 4 mm. Same locality on beach as those of *D. nigripes*. Length, 10–40 cm.

A. pallipes adult

Surface entrance into burrow. Course simple; unbranched; almost vertical, with obtuse angular bend changing course to horizontal; diameter constant. Vertical portion 2–3 cm. in length; horizontal, 2–15 cm.; diameter uniform, 6–8 mm. Found on wet edges of sand-bars and very wet portions of sand-spits.

H. tessellatum adult

Burrow position varying from surface to depth of 4–5 cm. Entrance on surface; raised, open. Tunnel with slight vertical inclination; position not horizontal; unbranched and simple. Diameter of burrow constant, course straight, no angular bends or curves. Diameter inside, 8–10 mm.; outside, 15–20 mm. Length, 3–20 cm. Rare on narrow inner beach; prevalent on sand-bars and sand-spits.

B. confusum adult

Surface entrance into burrow present; course simple and unbranched. Almost vertical; no horizontal elongation; slight terminal enlargements appear as "pits" in beach sand. Diameter constant with exception of terminal enlargement; 6–10 mm. Depth, 1–3 cm. On surface sand-bars and sand-spits.

H. americanum adult

Burrow depth varying down to 2 cm.; unbranched. Course essentially horizontal; tunnel irregular, with obtuse and acute angular curves. Diameter of burrow irregular, notable enlargements at curves in course; no extension in vertical direction. Diameter varying; 8–10 mm. Length, 3 -40 cm. On wet portions of sand-bars and sand-spits, occasionally on narrow inner beach.

B. confusum larva

Varying from surface to 2-3 cm. beneath. Course horizontal, very irregular, angular curves generally obtuse, occasionally acute.

Tunnel unbranched; diameter constant, increasing with later larval instars. Diameter of burrow of first larval instar less than 1 mm.; that of last larval instar as much as 5 mm. Length, 1–40 cm. Pattern constant for various instars. On surface and edge of sand-bars and sand-spits.

D. sphaericollis adult

Surface burrow easily visible. Course irregular, unbranched, twisting from right to left; curves gentle, never abrupt. Surface perforations sometimes present; few. Burrows sometimes uncovered. Diameter of burrow inside, 30 cm. On parts of narrow inner beach, barrier sand-bars, and sand-spits.

D. sphaericollis larva

Surface burrow; unbranching; course straight; few if any irregularities. Inside diameter in first larval instar less than 1 mm. Form of burrow constant for all larval instars, diameter increasing to 4 mm. Length varying with larval instars; 1–30 cm. Mostly on sand-bars and sand-spits.

H. tessellatum larva

Burrow entirely at surface; multiple branching; very complex; course of main tunnel irregular, curved, branches given off laterally; 2–6 branches not unusual. Number of branches not constant; diameter varying with larval instar, constant throughout whole system. Course of branches irregular; length always less than main tunnel. Diameter first larval instar burrow less than 1 mm., increasing with instars to 6 mm. Same pattern always in evidence. Length of main tunnel, 10–70 cm.; of first branches, 10–40 cm.; of second and third branches, 5–20 cm. On all types of inner beach, most common on sand-spits.

H. americanum larva

Surface burrow; easily seen in sand; branching and complex. Position entirely horizontal; course of main tunnel irregular; branches given off laterally, at about right angles to main burrow. Branches not rebranching; never so long as main tunnel; number 2 10; diameter varying with larval instar, but not in one complete system. Diameter in first larval instar less than 1 mm.; in last larval instar, 6 mm. Pattern constant. Length of main tunnel,

5–60 cm.; of branches 1–20 cm. Found on wet sand of bars and spits.

H. auromicans larva

Burrow extended entirely at surface; single; simple branching; course of main tunnel twisted, irregular. Small, short branches given off laterally from main tunnel, at about right angles, diameter less than that of main burrow. Course of branches rather straight, largely following direction taken by main tunnel, length much less than 1–4 mm. Length of main tunnel, 5–20 cm.; of branches, 1 8 cm. Mostly in sand-spits.

H. auromicans adult

Burrow near surface; entrance open; whole structure raised above sand surface; completely horizontal; doubly branching and complex; main tunnel absent. From entrance, tunnel extension straight for a few centimeters, branching in either or both directions; branching following tortuous path, sometimes approaching their own origin; rebranching, producing short burrows, also quite irregular. Diameter constant in all tunnels of the burrow system. Final formation very chaotic, no discernible beginning or end. Diameter inside, 4–6 mm.; outside, 7–10 mm. Length quite variable. On all sorts of beach.

Records, Plaster Casts

Permanent records of the form of burrows made by the different species were desirable. It was found that plaster of Paris might be used successfully if care was taken in the manner in which it was applied to the burrows. Molding clay was employed to construct a ring around the area of the burrow about an inch in height. This ring prevented the plaster from spreading over too large an area. After the ring had been made, the plaster was poured into it. The mixture of plaster and water was thick before it was poured on the burrow, so that it hardened very fast. When it had hardened sufficiently, it was carefully taken up. As it was raised the top of the burrow clung to the plaster mold, so that the burrow channel was uncovered. The exposed inhabitant was collected, placed in a vial containing alcohol, and given a serial number corresponding to the one written on the mold.

Molds of the burrows were allowed to dry until they were very hard. They were then covered with a very thin coating of soap solution, and another mixture of plaster was poured on the mold. This treatment kept the second pour of plaster from sticking to the mold, and it was easily removed as it reached a harder consistency. By this method a cast of the burrow was made from the mold that had been previously taken from the beach.

Attempts at photographing the burrows met with little success. The sandy beach does not possess a sufficient amount of contrasting color to produce good photographs.

General Biology

FOOD

As mentioned previously, the plankton in the inner-beach sand serves as food materials for the burrowing insects. This was shown through feeding experiments, in which the beetles reared were later dissected and the stomach contents examined. Some of the forms were selective in the type of plankters consumed, as will be described in the section dealing with general habits. Plankton was removed from the lake water by Birge cone nets drawn behind a motorboat and was always used soon after collecting to assure fresh food for the burrowers. If the sand already had a large amount of water, it might become flooded by the addition of the plankton. In such instances the excess was removed by withdrawing the water from the lower layers of the sand by means of a syringe bulb and attachments. In this manner the plankters settled upon and into the surface layer of the sand. Since not all the plankton in the sand was eaten it was necessary to change the sand at regular intervals in order to prevent undue putrefaction.

RESISTANCE TO SUBMERGENCE

Since submergence, due to waves and changes in water level, is a standing possibility, it was of interest to determine the ability of these air-breathing forms to resist immersion in water. Adults of the various burrowing species were continually submerged in water for varying intervals. Small beakers were inverted in larger containers filled with surface lake water. Adult beetles were placed under the smaller containers, so that their activity might be watched.

Cessation of activity was no index of the life of the insect. Careful records were kept on the time the insect was active under water. When activity ceased, it was removed at regular intervals to determine whether or not it was still alive. This was the only procedure that gave satisfactory information as to the time when the beetle died. In addition to the work done on adults, a like amount and kind of work was performed on the larvae of the same species. Results of these experiments are stated in Table II.

Immature forms are better able to withstand submergence than are the adults. The adults are not exposed to as great hazards, however, because they will at all times come to the surface of the water and float, whereas the large larvae seldom come to a floating position.

TABLE II

Results of Experiments on Resistance to Submergence

Five adults and two larvae of each species were tested.

Species	Adults		Larvae	
	Cessation of activity	Death	Cessation of activity	Death
B. confusum.....	1–2 min.	56–61 min.	25–28 min.	2.5–2.7 hr.
H. tessellatum	2–3 "	60–80 "	48–50 "	2.2–2.5 "
H. americanum.....	1–4.5 "	61–72 "	21–24 "	2.0 "
D. sphaericollis.....	2.8–3.1 "	60–61 "	31–34 "	2.5–2.6 "
H. auromicans.....	36–39 "	60–61 "	61–64 "	2.6–3.2 "

SEASONAL QUANTITATIVE VARIATIONS

In the spring adults of the burrowing species are not numerous in all localities around Douglas Lake. Narrow inner beaches are often completely barren of such species. Barrier-beach bars have a population that corresponds to the type and location of the bar, that is, those bars which have existed all winter and have never been completely submerged or are too far from the water line have burrowing species; those not corresponding to these requirements are not inhabited. Most sand-spits are inhabited with burrowers of different sorts. This is not true if the spit has been too far removed from the water's edge in the late fall of the previous year. Thus,

adults may be taken almost at will in sand-bar and sand-spit environments during the spring.

By midsummer the water in the lake begins to drop. This leaves exposures of sandy beach in those places where the shoal decline is not steep. These newly formed beaches become slowly inhabited by different kinds of burrowing species. After these beaches have become permanent, they are of a modified sand-spit form. Those adult forms which have migrated to this locality are of the old generation, i.e. those that emerged the previous fall. Drop in water level increases the quantity of usable beach for the burrowing species. As it happens, the eggs are laid from the spring to late summer. At the former time the water line is high, and the inhabited portions of the beach are, as has been indicated, the sand-bars and the sand-spits. The eggs hatch into larvae, which burrow in or near the locality where they develop. Sometimes various outside influences disseminate the eggs, so that burrowing larvae are apt to be found on any beach, but are most prevalent on bars and spits. The larvae pass their entire existence in such a situation and pupate at about the same place. After the pupal stage has been completed, the newly formed adults do not migrate far from the place of their emergence. In many instances final transformation occurs so late in the season that, when adults do emerge, they never come to the surface of the sand, so that migration from that area is not apparent. The emergence of newly formed adults thus increases the quantity in the older sand-bars and sand-spits, even though some specimens from the previous generation have migrated.

In the late fall, when ice coats the surface of the lake, the more recently formed beach is covered with ice sheets, and those burrowers which have lived up to this time on the beach die off. Since a greater number of the newly emerged beetles have remained in the older sand-bars and sand-spits, they survive and extend their burrows deeper into the beach. The water is not generally sufficient in the deeper layers of the sand to permit total freezing and, in addition, the upper layers of the sand are at most times protected by a blanket of snow. In this manner the adults of the various species overwinter. The following spring they are found in the localities in which they have spent the winter.

The variation in the quantity of larvae is obvious from what has been related concerning the life history of the burrowing species.

In the early part of the summer season few if any can be collected. In midsummer a few begin to appear, and later on they become quite numerous.

In the early spring adults of *H. auromicans* comprise the bulk of the population. Almost every sand-bar and sand-spit supports many individuals of this species at that time of the year. As the season progresses, the adults oviposit and gradually die off. Near the end of the summer the only adults that remain of this species are those that have recently emerged and that live in the older sand-bars and sand-spits around the beach. These stay where they emerged until the following spring. The larvae of this species are especially numerous from about the middle or the last of August until pupation, which occurs from the middle of September on until late fall.

The adults of *B. confusum* are slightly more numerous in the fall than in the spring. The reason for the larger number in the fall is explained by the fact that the adults of the older generation do not die off until late in the season. Those individuals that have deposited their eggs continue their burrowing activities all through the summer period on into the fall, so that when the new generation comes on they still exist. The larvae of this species are not produced in such great numbers as those of the species just discussed. They are found in collections taken in the latter part of July until the last part of August. By this time most of them have pupated. Pupae are often taken in collections as late as the first part of September, after which time most of the adults have emerged.

The adults of *B. confusum* are the most active of the burrowing species. In the daytime they occur on the surface of sand-bars and sand-spits, actively feeding or running on the moist sand. A few individuals occupy the burrows throughout part of the day, which makes them less obvious. Their habits undoubtedly aid in causing this species to appear more numerous than some of the others.

Adults of *H. tessellatum* resemble those just discussed in seasonal distribution. The spring and summer is a time of low population. Only those adults which have overwintered are present. The incidence of death during the winter season is higher in this species than in any other, so that the number of adults is not large. The eggs are laid about the middle of the summer season, slightly before those of the other species. The larvae, being the largest of this

burrowing group, are taken more often in collections. Not only are they collected more frequently, but their burrows appear much more commonly on the beach. The larvae pupate earlier than most of the other species on the inner beach and, since their period of pupal life is about the same as that of other species present, the new generation of adults appears early. As in the species just described, adults appear in greatest number late in the summer or early in the fall. It happens that the peak in the number of adults occurs at the time described above, and when no other burrowing species are present in significant numbers.

Adults of this species are constant in their time of maximum appearance, as has been shown during four seasons of study. This maximum number also shows that the life cycle is slightly more than a year in length. Most of the adults live a complete year. They are the largest of the true burrowers.

The adults of *H. americanum* are never so common as those of the species just described, although they may be collected in greater numbers in early spring. Those that have overwintered in the sandbars and sand-spits comprise the largest groups. The females deposit their eggs near the middle of August. At most times the larvae appear in the early fall; they pupate when the season is farther along.

The life history of *D. sphaericollis* does not differ greatly from that of the species just described. It is noted that the adults are commoner in the spring than are those mentioned above, although they are doubtless more numerous at all times. In the early fall the adults begin to die, so that collections at that time show a marked decrease, which is more obvious than in any other species. The larvae and the pupae were never numerous in collections from any lake.

HABITS

Food

As already mentioned, the plankton materials coming into the inner beach make up the food for the burrowing insects. It is interesting to note that the various species of beetles in this amphibious group have different food habits. As the plankton is made up of zoöplankton and phytoplankton, great diversity in kinds of food may occur. The habits of selection of food will be described for each of the burrowing species.

The larvae and the adults of *H. auromicans* have practically the same food habits. The phytoplankton, which comprises a rather large proportion of the plankton crop in Douglas Lake, is used for food. The water content in the sand-bars and sand-spits is sufficient to maintain both single-celled and colonial algae. On numerous occasions the writer has observed adults of this species feeding on *Gloeotrichia* and, at times, on the simpler blue-green algae, such as *Gloeocapsa* and *Merismopedia.* Dissection of the stomach with its contents has never revealed any sort of zoöplankton; nor has this species been observed feeding on animal life of any description.

B. confusum, in the adult stage, feeds on zoöplankton, or on some of the smaller visiting beetles. Most of the plankton forms serving as food are Rotifera, Copepoda, and Cladocera. A few Copepoda recovered from the stomachs of this species were of the kind also found in the sand of the beach, although never in plankton collections from the lake. This beetle has been observed feeding on its own members, but such cannibalism has been mostly restricted to the rearing cages, where sufficient food of other sorts was not furnished.

The food habits of the larvae of this species are not especially different from those of the adults. If possible, the younger larval instars prey on the smaller plankters. When the plankters are almost as large as the predators, an interesting struggle sometimes ensues, in which the larva is generally victorious.

The adults and the larvae of *H. tessellatum* are probably the least selective of any species of this assemblage. They are quite predaceous. The largest Crustacea and Algae serve as food for the adults. The daily consumption is most astounding when one considers the size of the animal doing the feeding. They get the planktonts that are in the sand or they may migrate down to the edge of the water and pick up those that have been washed in. They have been maintained for a long time on Algae, and they have been kept alive on animals for just as long a period without any apparent detriment. As in the species previously described, they are cannibalistic if the necessity arises. Individuals which have recently emerged are much more exposed to capture.

H. americanum, in the adult stage, feeds on the zoöplankton more than do the larvae. The adults, as shown by dissection and observation, do not generally feed on the phytoplankton, although they may in case of want. The larvae, on the other hand, resemble

those of the species just described in being unselective in their diet. Almost any living thing found in the plankton material is eaten. Not infrequently cannibalism is practiced where they are brought in close proximity. The older larval instars do feed on members of their own size, but the tendency is to feed on the younger ones. In like manner the adults prey on other beetles that are on the beach. These are not often members of their own species, but generally they are some of the smaller visiting forms. Cannibalism has been observed but rarely in nature.

D. sphaericollis is the only species of this group that is truly omnivorous. Living plankton, or almost any organic remains, is eaten freely. This species commonly feeds upon the surface débris of the inner beach. Unlike most of the other species, it is not generally found feeding on the materials that are in the sand of its burrow. Its burrows are apparently used only as a housing place, but never so much so as those of the other species. The larvae are not carnivorous; they feed only on plankton materials. This peculiar type of feeding is especially interesting, since it involves a habit unique in this association.

Very closely associated with this group is a staphylinid, *Bledius sp.*, which doubtless aids in completing the work that has been started by the other species, i.e. this form is almost entirely a carrion feeder and serves to clean up the sand materials of organic remains.

Breeding

The breeding habits of the various species of this group have been observed numerous times. Some rather distinct peculiarities have been seen which are uncommon to those species that do not burrow and which have doubtless developed along with the burrowing habit. These do not normally occur in all the species, but they will be described briefly for those insects that show them.

B. confusum, at most times, breeds on the open beach, carrying on the mating activities in a manner typical of active carabids. The males may mate with as many as twenty females in a short interval of time. Apparently, they do not often perform the mating activities in the burrows, although such mating has been found a very few times.

H. auromicans differs slightly in its breeding habits from the

species just described. Most of the mating occurs during the night and may take place in the burrow or on the surface of the beach. Individuals of this species are never overly active; most motions are accompanied by a certain amount of awkwardness. The males have not been observed to mate with more than one female, even in a long interval. Since these beetles are prone to carry on most of their general activities at night, breeding is a nocturnal performance. The fossorial prothoracic legs are of use to the male in grasping the female, although there are no other special morphological adaptations. The males possess stridulating ridges along the ventral side of the first abdominal segments, which they use on various occasions. Stridulations are made in flight or while the males are on the surface of the beach.

H. tessellatum and *H. americanum* have about the same sort of breeding habits. These beetles are quite shy, enough so that mating has been observed only a few times. There are no special morphological adaptations for this behavior. The prothoracic legs of the male are used for grasping the female, encircling the prothoracic portions. The mating, so far as observed, always occurs in the burrows that have been made by the adults. It takes place at night or just shortly after sunset. Since the burrows of this species are occupied by a single individual, the male generally migrates to the burrow of the female during the mating season. Shortly after mating the male returns to his old burrow or constructs a new one. This account applies to individuals of both species. It happens that *H. tessellatum* is the shier of the two, and although the individuals of this species are much more prevalent than those of *H. americanum*, few records of mating are at hand.

D. sphaericollis does not resemble many of the other carabids in its breeding habits. It carries on most of its activities at night, usually in the burrows. The prothoracic legs of the male of this species, which are fossorial, prove useful in mating. Since only one individual of this species lives in a single burrow, one of the sexes is required to migrate. Observations show that either the male or the female will go from its own burrow to the burrow of the other.

Egg-laying

All individuals in this group, with the exception of *H. auromicans*, use sand in constructing protective capsules for the eggs. Ovi-

position occurs mainly during the night or just after sunset. It was observed both in rearing chambers and in nature.

H. auromicans deposits several eggs at one time, which remain together. The bottom of the burrow is usually lined with excreta, on which the eggs are placed. After the eggs have become embedded in this mat of excreta, they are apparently safe from destruction. The visiting forms rarely if ever eat the eggs, even though they come into contact with them. The cluster contains from ten to thirty eggs and resembles a bunch of grapes. These eggs are collected very easily because they float on the surface of the water; they are the only eggs of all the burrowing species that do.

The other members of this group differ from the species just described in the manner in which they place their eggs. In every instance there is, surrounding the individual egg, a protective capsule of sand that is formed in a very clever manner. The egg, when it is thrust out by the female, is covered with a layer of mucilage-like material. When this sticky surface touches the sand, a number of grains adhere to it. The female keeps her ovipositor in contact with the surface of the egg as it is thrust out, so that there is no mucilage-like material at that place. They remain in contact until the material on the outer surfaces of the egg has dried and a complete capsule is formed. At this time the ovipositor is drawn in and the egg remains where it was placed, with a complete covering of sand, except for the point of attachment of the ovipositor.

B. confusum exercises no choice in the distribution of its eggs. If the females are on the surface of the sand during the egg-laying time, the eggs are placed there and at random. If, on the other, hand, they are in their simple shallow burrows, the eggs are deposited in the bottom. *H. tessellatum* and *H. americanum* are a little more selective in the manner in which the eggs are placed. The eggs are deposited at the time of maximum activity of the adults, so that it is not to be expected that the egg will always be laid in the burrows. It is very difficult to distinguish between the eggs of these two species. The egg-laying habits seem to be almost identical.

The eggs of *D. sphaericollis* are the smallest of all that have a protective sand capsule around them. Most females are in the burrows during egg-laying time. However, they may place eggs in different sorts of débris or detritus on the edge of the inner beach or

they may oviposit on the surface of the inner beach in proximity to the region of their burrows.

Life-History Stages

Heterocerus auromicans (Pl. LXIII, Fig. 1)

Egg

Length, with transparent cover, 0.63–0.69 mm. Width, with cover, 0.48–0.53 mm. Egg length, 0.50–0.57 mm.; width, 0.38–0.43 mm. Dimensions varying with development. Eggs in groups of 10–30. Egg covered separately with transparent tough membrane; surface coarsely reticulate; slightly oval to spheroidal; one end slightly pointed; opposite end rounded to oval; micropyle apparent, on pointed end. Color whitish gray, becoming yellow as egg matures.

Larval Instars

Length of each larval instar 5–9 days. (Measurements of length and head capsule made on preserved materials.) First instar: width of head capsule, 0.32–0.34 mm.; length, 1.1–1.5 mm. Second instar: width of head capsule, 0.41–0.45 mm.; length, 2.0–2.5 mm. Third instar: width of head capsule, 0.53–0.58 mm.; length, 3.9–4.6 mm. Fourth instar: width of head capsule, 0.66–0.74 mm.; length, 6.0–7.0 mm.

Morphological characteristics similar for all larval instars, with the exception of head capsule and length. The description of the fifth instar will serve for any of the larval instars.

Fifth Instar (Pl. LXIII, Fig. 1)

Length of body, 10–12.2 mm.; average, 10.8 mm. Width of head capsule, 1–1.5; average, 1.3 mm. Width of prothorax, 1.4–1.8 mm.; average, 1.6 mm. Length of head and thorax slightly more than one third of entire body length. Shape of head, flattened, convex dorsally; thorax compressed, ventral surface flattened, raised dorsally; abdomen distinctly rounded, subcylindrical, becoming more nearly cylindrical and tapering posteriorly from thorax. Color of body light brown to yellow; head darker, becoming lighter posteriorly.

Head subrectangular; clypeus small; labrum projecting as reg-

ular rectangular plate; mandibles simple, not dentate; maxillae simple, cardo small; palpus almost invisible; labium enlarged, covering large portion between genae; mentum small; antennae very small; scape very small; flagellum composed of three small segments. Ocelli dorsal and lateral, five in number; one ventral, lateral to labium. Dorsal surface of head dark to light brown; Y-shaped epicranial suture; no median suture. Ventral side of head dark anteriorly and laterally; median portion light.

Prothorax subquadrate; angles absent; dorsal plates subtruncate both anteriorly and posteriorly; lateral portions rounded. Entire margins pubescent, sparse in anterior region, dense in posterior. Lateral parts with coarser pubescence; primary setae present in anterior part, three apparent; one prominent in posterior, more removed from edge. Median suture present, connecting with Y-shaped epicranial suture anteriorad, recognized by its light coloration. Anterior two thirds dark, including complete margins; posterior one third light; suture inverted-pyramidal, very faint, median and dorsal.

Mesothorax subquadrate; posterior lateral margins forming obtuse angles. Distinct intersegmental line, sometimes appearing double. Dorsal plates slightly rounded in anterior part, truncate in posterior; lateral margin rounded, not extending to margin of body; sclerites well removed from intersegmental lines in both anterior and posterior. Entire surface of plates pubescent, more apparent near median suture and posterior margin, sparse in lateral parts. Primary setae scattered, anterolateral placement of three in group; four prominent on anterior part of each dorsal plate; three in posterolateral parts of each; two in posteromedian portions; and variable numbers found on margins of body. Mesothorax yellow; pubescence dark; primary setae black. Two dark markings on each dorsal plate; one circular, placed anteromedian; the other oblong, larger, and median.

Metathorax subquadrate; angles absent; sides distinctly rounded. Distinct intersegmental line, posterior one double. Dorsal plates slightly curved at anterior end, less curved posteriorad, curved and rounded latera, closely following contour of body, not extending to margins, removed in both anterior and posterior from intersegmental lines. Pubescence slight, present mostly along median suture, only on plates. Primary setae unevenly scattered; four

on anteromedian portions; four to five anterolateral; four across posterior margin of plate; variable number on lateral margin outside plates; number not always constant; small setae not considered. Color of metathorax yellow; pubescence brown; setae black. Two dark spots on each dorsal plate; one circular, placed anteromedian; the other subquadrate, large, placed median.

Ventral aspect of thorax simple; large portion of each segment occupied by origin of coxae.

Prothoracic coxae wide; procoxacava circular, length and width about equal, shape conical, tapering distad, pubescent. Trochanter small. Femur twice as long as wide, pubescent, diameter about constant, cylindrical. Tibia about three times longer than wide; pubescence at proximal end, tapering toward distal portion; outer portion with three obvious spines; inner portion with three longer and more pointed spines; tarsus subcylindrical, not pubescent, four times longer than wide, tapering distally; one prominent spine on outside; inside, concave, excavated near tip. Leg fossorial.

Meso- and metathoracic legs, similar; pubescence variable; femora more flattened; less fossorial.

Dorsal aspect of nine abdominal segments similar, tapering posteriorly; number and arrangement of dorsal plates variable; first four subrectangular; fifth concavo-convex; sixth rectangular; seventh and eighth subquadrate; ninth flattened anteriorly, rounded posteriorly; tenth not visible; no posterior projections; number and position of primary setae variable; general appearance pubescent; dorsal plates light to dark brown; intersegmental regions light yellow to white; setae black.

Ventral aspect simple; first six segments with chitinized plates, pubescent; last three without plates, pubescent; tenth segment turned under.

Spiracles on mesothorax and first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 26)

Typical exarate pupa. Total length, 5.8–6.4 mm.; average, 6.0 mm. Width including wings (not expanded), 2.8–3.3 mm.; average, 3.0 mm. (Measurements made on preserved materials.) Body color light cream to yellow. Eyes reddish brown, ocelli not apparent. Setae of varying length and size on surface of pronotum and abdomen. Pubescence heavy, distinct, coarse. Head with mouth parts

formed, resembling those of adult; entire head turned under pronotum; not visible from above. Pronotum most apparent structure on dorsal surface. Abdomen with seven segments. Pro- and mesothoracic legs distinctly folded on ventral side of thorax; bend at femorotibial joint. Metathoracic legs straight, projecting beyond metathoracic wing pads. Length of pupal stage 5–10 days.

Bembidion confusum (Pl. LXIII, Fig. 6)

Egg

Length of egg, with sand capsule, 1.76–2.00 mm. Width, with sand capsule, 1.43–1.66 mm. Length, without sand capsule, 0.78–0.82 mm.; width, 0.50–0.52 mm. Dimensions with sand capsule sometimes more variable.

Eggs occurring singly, each covered with sand capsule; capsule opening on one side; number of sand grains variable. Chorion transparent; surface finely pitted, under part reticulate; oblong, elongately oval; one end slightly pointed, opposite end distinctly rounded. Micropyle variable in appearance, on pointed end of egg. Color creamy to dark yellow, changing to buff when mature. Two brownish groups of ocelli showing through chorion immediately before hatching.

Larval Instars

Length of each larval instar 5–9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.40–0.46 mm.; length, 3.2–4.8 mm. Second instar: width of head capsule, 0.54–0.57 mm.; length, 5.2–6.0 mm. Third instar: width of head capsule, 0.65–0.71 mm.; length, 6.4–7.2 mm. Fourth instar: width of head capsule, 0.82–0.90 mm.; length, 8.6–9.8 mm.

Morphological characteristics similar in all larval instars, with exception of head capsule and length. The following description of the fifth instar larva is applicable to all.

Fifth Instar (Pl. LXIV, Fig. 5)

Length of body, 10.9–12.0 mm.; average, 11.3 mm. Width of head capsule, 1.0–1.3 mm.; average, 1.2 mm. Width of prothorax, 1.1–1.4 mm.; average, 1.3 mm. Length of head and thorax slightly more than one third of entire body length. Head subtriangular,

rounded on dorsal, flattened on ventral side. Thorax rounded on dorsal; prothorax equal in length to meso- and metathorax; flattened on ventral. Abdomen subcylindrical, slightly compressed dorsoventrad, tapering posteriorad from fifth abdominal segment. Color light brown to very light yellow; dorsal plates much darker.

Head subtriangular; clypeus small; labrum triangular, not extended; mandibles curved, falcate; retinaculum on inner edge near middle; maxillae large; cardo cylindrical; stipes medium; galea small; palpus cylindrical, four-segmented; prementum with setae; mentum distinct; ligulae and paraglossae apparent; labial palpus with three distinct segments; antennae longer than mandibles; scape distinct; flagellum four-segmented. Ocelli six, lateral, near antennal base. Mandibles lateral and posterior, parts of head dark; rest of head light brown to yellow. Y-shaped epicranial suture. Ventral side of head simple; gula large; entire surface yellow.

Prothorax subrectangular, elongate, subcylindrical, compressed on ventral side; dorsal plates covering slightly over one half of prothoracic surface; truncate on anterior end; anterolateral angles acute; margins slightly rounded; posterior edges rounded; margins of plates removed from those of body. Primary setae small; five across anterior edge of plates; four across posterior border; sparse on lateral edges; variable number on body margins. Median suture connecting with Y-shaped epicranial suture, light-colored. Median portions of plates dark, remainder light.

Mesothorax subquadrate; slightly wider than long; one half as long as prothorax. Intersegmental lines double. Dorsal plates covering most of surface, subtruncate at both anterior and posterior ends, removed from lateral margins; lateral edges of plates slightly rounded. Primary setae small, numerous; line across anterior edge composed of seven on each plate; five in transverse line through median region; four across posterior edge. Sparse pubescence on margin outside plates. Dark markings near median region of each plate, slightly oblong, concavo-convex; remainder of plates light brown; portions outside yellow. Light median suture very apparent.

Metathorax subquadrate, about as wide as long. Distinct intersegmental lines double. One half as long as prothorax. Dorsal plates covering most of surface, slightly curved or rounded, removed from margin of body, posterior edge truncate. Primary setae small, numerous, unevenly scattered; generally five setae on anterior mar-

gin of each plate; three near median portions; eight across posterior edge of each plate; smaller setae variable. Regions outside plates possessing few if any setae or little pubescence. Dark markings covering small area of each plate, about half as long as width of plate, oblong, concavo-convex; remainder of plate dark yellow; region outside plate light yellow. Light median suture very distinct.

Ventral surface of thorax plain; region occupied by coxae.

Prothoracic leg: coxae wide; procoxacava circular, short, conical, tapering distad; trochanter small, not much more than simple ring; femur longer than wide, cylindrical; three sharp, distinct spines on inside; tibia longer than wide, flattened on inside, slightly grooved, distal end dilated; ring of sharp, distinct spines, seven in number; tarsus three-segmented; first slightly longer than wide, flattened on inside; distal ring of spines five in number; second segment conical, tapering distad, flattened on inside; two spines on outside, proximal one large, distal small; third segment, conical claw, tapering on distal end to point.

Meso- and metathoracic legs similar.

Dorsal aspect of eight abdominal segments similar, each wider than long; arrangement of dorsal plates variable, each successive plate from first to eighth segment longer; markings on each plate, first set with two oblong, concavo-convex markings; each of following seven with two oblong and two circular markings. Each segment with lateromedian protuberances; each protuberance with primary setae, varying from three to five. Number of primary setae on plates variable, none on other regions of segments. Color of distinct markings dark; plates light brown, remaining portions light yellow to white. Ninth segment small; two caudal appendages, about twice as long as dorsal portion of segment; appendages slightly curved, cylindrical; three primary setae on outside, one apical. Tenth segment small, developed as pygopod.

Ventral aspect of abdomen plain, pubescent.

Spiracles on laterodorsal portions of first eight abdominal segments, not apparent on thorax.

Pupa (Pl. LXIV, Fig. 28)

Typical exarate pupa. Total length, 5.2-6.0 mm.; average, 5.5 mm. Width including wings (not expanded), 2.6 3.4 mm.; average,

3.0 mm. (Measurements made on preserved materials.) Body color white to light cream. Eyes distinctly reddish brown. Setae sparse, few on thorax and abdomen. Pubescence sparse, fine. Entire mouth parts formed as in adult; head depressed forward, toward ventral side of thorax. Pronotum wide, distinct, largest segment of body. Abdomen with nine segments. Pro- and mesothoracic legs folded on ventral side of thorax; fold at femorotibial joint. Metathoracic legs almost straight, reaching posterior end of abdomen. Length of pupal stage 5–10 days.

Dyschirius sphaericollis (Pl. LXIII, Fig. 10)

Egg

Length of egg, with sand capsule, 1.4–1.6 mm., width, 1.23-1.33 mm. Egg length, 0.75–0.77 mm.; width, 0.46–0.49 mm. Measurements with capsule sometimes more variable. Eggs occur singly, each with sand capsule; opening on side or end; number and size of grains variable, often small to medium. Chorion very transparent; surface smooth; lower layer coarsely reticulate; reticulum areas octagonal to circular. Shape oval and ellipsoidal; one end slightly rounded, opposite partly pointed. Micropyle in center of pointed end, not protruding. Color light cream to white, always lightest of group having sand capsules. Two reddish brown groups of ocelli showing through chorion as egg nears time of hatching.

Larval Instars

Length of larval instars, 5–9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.19–0.22 mm.; length, 1.9–2.6 mm. Second instar: width of head capsule, 0.25–0.30 mm.; length, 2.8–3.2 mm. Third instar: width of head capsule, 0.32–0.36 mm.; length, 3.6–4.0 mm. Fourth instar: width of head capsule, 0.42–0.47 mm.; length, 4.8–5.8 mm.

Morphological characteristics similar in all larval instars with exception of head capsule and length. The description of the fifth instar larva is applicable to all.

Fifth Instar (Pl. LXIII, Fig. 9)

Length of body, 6.7–7.2 mm.; average, 7.0 mm. Width of head capsule, 0.66–0.70 mm.; average, 0.68 mm. Width of prothorax,

0.78–0.80 mm.; average, 0.79 mm. Length of head and thorax about one third of entire body length. Head flattened, slightly convex on dorsal side; thorax rounded; prothorax longest segment; abdomen cylindrical, tapering posteriorad from sixth segment. Color dark, with exception of intersegmental region.

Head subrectangular; clypeus wide, not large; labrum wide, pointed on anterior end, small; mandibles curved, falcate; retinaculum on inner edge near middle; maxillae apparent; cardo not large; stipes, subgulae, palpifer fused; palpus cylindrical, four-segmented; galea small, two-segmented; prementum with setae; mentum slightly elongate, distinct; lingulae obvious; labial palpus with three apparent segments; antennae not quite so long as mandibles; scape round, distinct; flagellum four-segmented. Ocelli six, lateral, color almost uniform, light brown. Y-shaped epicranial suture. Ventral side of head light, plain; gula narrow; genae almost flat.

Prothorax elongate, subcylindrical, slightly wider in posterior portion; entire dorsal surface heavily chitinized; plates covering entire surface area. Primary setae absent; pubescence slight, only on margin, very fine. Median suture connecting with Y-shaped epicranial suture. All parts black, with exception of median suture.

Mesothorax subquadrate, wider than long. Intersegmental line single in anterior, double in posterior. Dorsal plates covering entire surface. Primary setae absent, sparse, fine; pubescence on margins of segment. Entire surface dark, uniform, except median suture.

Metathorax subquadrate, distinctly wider than long. Intersegmental lines double. Dorsal plates covering entire surface except extreme posterior portion. Primary setae absent; pubescence extremely sparse, fine, only on margins. Color dark, with exception of posterior margin of segment and median suture, both lighter.

Prothoracic leg: coxae slightly protruding; procoxacava circular, short; trochanter not so wide as coxa or femur; femur slightly wider than long, conical, tapering at distal end, composed of two lateral parts, equal in width; three primary setae on outer side; tibia about four times longer than wide, composed of two parts, proximal one half as long as distal, cylindrical; two to six primary setae on outer side; tarsus three-segmented, first, cylindrical; about four times longer than wide; primary setae variable, generally two on outside, three on inside; second segment about five times longer

than wide, cylindrical; third segment, conical claw, tapering on distal end to point.

Meso- and metathoracic legs similar.

Dorsal aspect of seven abdominal segments similar; arrangement of dorsal plates similar, each with plates extending completely to anterior portion of segment; edges truncate, slightly short at posterior end; margins of plates rounded, not extending to margin of body; successive segments about same size from first through sixth; seventh slightly smaller; eighth smaller; dorsal plates covering complete surface; ninth segment conical, tapering distal; plates complete; urogomphi small, shorter than tenth segment; tenth segment small, conical, pointed. Pubescence slight, mostly on body margins. Color dark, except in intersegmental region and body margins.

Ventral aspect of abdomen flat; one large oval plate near anterior part of each of first eight segments; five longitudinal plates, two outer, extending length of segment; two lateral, to middle plate, slightly shorter; middle plate shortest, in posterior part. Ventral aspect of ninth and tenth segments plain.

Spiracles visible on laterodorsal portions of first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 25)

Typical exarate pupa. Total length, 5.0–6.4 mm.; average, 6.0. Width including wings (not expanded), 1.8–2.5 mm.; average, 2.2 mm. (Measurements made on preserved materials.) Color of body cream to dull yellow. Eyes a reddish brown color. Setae of varying length and size, sparsely scattered on dorsal surface of thorax and abdomen. Pubescence very fine, slightly visible. Head with mouth parts resembling those of adult, whole structure bending forward. Pronotum large, most apparent structure on dorsal surface. Abdomen with nine segments. Pro- and mesothoracic legs folded on ventral side of thorax; fold at femorotibial joint. Metathoracic legs straight, reaching posterior end of abdomen. Length of pupal stage 5–10 days.

Homophron tessellatum (Pl. LXIII, Fig. 14)

Egg

Length of egg, with sand capsule, 2.06–2.33 mm.; width, 1.73–2.06 mm. Egg length, 1.15–1.19 mm.; width, 0.72–0.75 mm. Di-

mensions with capsule sometimes more variable. Eggs occur singly, each with sand capsule, opening on side. Sand grains variable in number and size, generally coarse. Chorion partly transparent; surface irregular, slightly rough; lower layer densely reticulate; reticulum areas irregular to circular. Shape elliptical, slightly elongate; ends rounded, very similar. Micropyle not apparent. Color tan to dark buff. Two reddish brown groups of ocelli appearing through chorion near hatching time.

Larval Instars

Length of each larval instar 5–9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.26–0.30 mm.; length, 1.0–3.8 mm. Second instar: width of head capsule, 0.39–0.42 mm.; length, 2.5–6.0 mm. Third instar: width of head capsule, 0.60–0.63 mm.; length, 3.7–7.8 mm. Fourth instar: width of head capsule, 0.92–0.95 mm.; length, 5.0–10 mm.

Morphological characteristics similar in all larval instars with exception of head capsule and length. The description of the fifth instar larva may be applied to all. Length of entire body extremely variable. Number and placement of setae slightly variable.

Fifth Instar (Pl. LXIII, Fig. 13)

Length of body, 12.4–13.2 mm., average, 12.8 mm. Width of head capsule, 1.1–1.4 mm., average, 1.2 mm. Width of prothorax, 1.7–2.0 mm.; average, 1.8 mm. Length of head and thorax one third of length of entire body. Head subrectangular, slightly rounded on dorsal. Thorax rounded dorsally; prothorax about equal to meso- and metathorax in length. Abdomen slightly compressed dorsoventrally, tapering from third abdominal segment posteriorly to end. Color light brown to light yellow, dorsal plates darker than other parts.

Head subrectangular; clypeus small, emarginate; labrum small, triangular, pointed on anterior end; mandibles, large, curved, falcate; retinaculum on inner edge near middle, bicuspidate: maxillae rather large; cardo medium; stipes, subgalea, palpifer fused; palpus cylindrical, four-segmented, tapering to point distally; galea two-segmented, tapering to point distally; lacinae apparent; prementum with setae; mentum distinct; ligulae membranous; labial palpus with three distinct segments, tapering distally. Antennae slightly

longer than mandibles; scape round, distinct; flagellum four-segmented; third of same length as both first and second. Ocelli six, lateral. Color, dark band near posterior part of head; remainder light brown to yellow. Y-shaped epicranial suture. Ventral side of head plain.

Prothorax narrow at anterior end, widened at posterior; width about equal to length of segment; dorsal surface with plates complete, except at posterior end; distinctly rounded at anterior end, subtruncate posteriorly, slightly rounded on lateral edges. Primary setae absent on dorsal surface of plates, sparse on lateral portions of segment; pubescence distinct and large on margins. Median suture, connecting with Y-shaped epicranial suture. Distinct transverse marking in median portion, concavo-convex. Anterior edge of segment bordered with longitudinal dark markings; posteromedian part dark, remainder light brown to yellow.

Mesothorax subrectangular, wider than long. Intersegmental lines single. Dorsal plates covering about half of segment surface; truncate in anterior portions; angles rounded; posterior margin truncate, distinctly rounded at margin; lateral parts distinctly rounded. Primary setae numerous, of variable size; large setae, two on each plate, extreme anterior end, four across each anterior margin just posterior to edge; four across posterior border; extending slightly on lateral; variable number on body margins; pubescence extensive, very fine, slightly visible. Color, dorsal plates light brown, remainder of body light yellow. Median suture light, distinct.

Metathorax subrectangular, distinctly wider than long. Intersegmental lines single. Dorsal plates extending over most of surface longitudinally, distinctly removed from margins of segment. Anterior margin of plates subtruncate; posterior margins turning in at center; entire margins curved, rounded on lateral. Primary setae numerous, variable; distinct setae, seven across anterior margin of each, one anteromedial in each; two posterolateral; six across each posterior margin. Only very apparent setae counted. Pubescence present on edges of dorsal plates, very fine, especially on body margins. Dark transverse line across dorsal plate, not complete; in anterior portion. Median suture apparent. Color of dorsal plate, except the dark line, a light brown; remainder of segment yellow.

Ventral aspect of thorax simple; large portion of each segment taken up by coxal space.

Prothoracic leg: coxa wide; procoxacava oval, wider than long, short; trochanter, equal in diameter to coxa, very short. Femur about as long as width of base, conical, tapering distad; base with long pubescence; five primary setae on outer side. Tibia cylindrical, three times longer than wide, slightly enlarged distally; six large spines on sides, largest on distal part, diminishing proximally. Tarsus three-segmented; first segment as long as width of distal portion; ring of seven spines around distal enlargement; second segment one fourth longer than wide, cylindrical; distal ring of six spines around slightly enlarged portion; third segment much longer than wide, conical, tapering distally; two claws.

Meso- and metathoracic legs similar. Some slight modification and rearrangement of spines.

Dorsal aspect of nine abdominal segments similar; all wider than long except the eighth, which is subquadrate. Arrangement and shape of dorsal plates variable: first subrectangular, second subovate, third subtriangular, fourth subtriangular, fifth subpyramidal, sixth subpyramidal, seventh and eighth subquadrate, and ninth subovate. All plates removed from body margins; transparent layer on outside of body margins. Each segment with mediolateral protuberances; each protuberance with primary setae, four to five. Number of primary setae on dorsal plates variable, none in other regions; absent on plates in eighth and ninth segments. Color of dorsal plates light brown, body color yellow, transparent margin almost clear. Ninth segment small, two caudal appendages (urogomphi) slightly more than twice length of segment proper. Urogomphi cylindrical, slightly tapering distally; primary setae numerous, about fourteen present. Tenth segment developed as pygopod.

Ventral aspect of abdomen plain, except double patches of primary setae on each segment. Setae very small.

Spiracles on dorsolateral portions of first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 23)

Typical exarate pupa. Total length, 5.6–8.4 mm.; average, 7.5 mm. Width including wings (not expanded), 3.2–4.0 mm.; average, 3.6 mm. (Measurements taken from preserved materials.) Color of body white to light cream. Eyes a reddish brown color. Setae absent on dorsal surface of thorax, present on dorsal surface of ab-

domen, two groups on each side of median line. Pubescence not evident. Head with mouth parts resembling those of adult; head turned under prothorax. Pronotum large. Abdomen with nine segments. Pro- and mesothoracic legs folded on ventral side of thorax; fold at femorotibial joint. Metathoracic legs almost straight, sometimes extending beyond posterior end of abdomen. Length of pupal stage 5–10 days.

Homophron americanum

Larval Instars

Length of each larval instar 5–9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.22–0.28 mm.; length, 1.0–3.0 mm. Second instar: width of head capsule, 0.37–0.41 mm.; length, 2.0–5.0 mm. Third instar: width of head capsule, 0.52–0.59 mm.; length, 3.0–6.2 mm. Fourth instar: width of head capsule, 0.86–0.90 mm.; length, 5.8–9.2 mm.

Morphological characteristics similar in all larval instars with exception of head capsule and length. The following description of the fifth instar larva may be applied to all. Arrangements of setae differing slightly in various instars.

Fifth Instar (Pl. LXIII, Fig. 17)

Width of head capsule, 1.1–1.3 mm.; length, 7.8–12.5 mm. Other measurements similar to those of *H. tessellatum.*

Head parts similar to those of *H. tessellatum;* color darker; slight difference in arrangement of setae.

Prothorax similar to that of *H. tessellatum.* Setae on surface of dorsal plates. Color different; anterior margin black; remainder dark brown.

Mesothorax similar to that of *H. tessellatum.* Dorsal plates covering more of segment. Primary setae variable, about as numerous. Color darker.

Metathorax similar to that of *H. tessellatum.* Dorsal plates covering more of segment. Primary setae variable, about as numerous. Color darker.

Pro-, meso-, and metathoracic legs similar to those of species mentioned above. Spines variable. General proportions not differing greatly. Color darker.

Abdominal segments similar in arrangement, number, and forma-

tion; about the same as those of *H. tessellatum.* Dorsal plates darker, with dark markings. Primary setae numerous, distinct; arrangement slightly variable. Color of segments, not including dorsal plates, light brown. Mediolateral protuberances, with four to five primary setae. Urogomphi about the same as those in *H. tessellatum.*

Ventral aspect of abdominal segment simple, two rows of primary setae very obvious.

Spiracles present on laterodorsal portion of first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 27)

Typical exarate pupa. Total length, 5.5–7.6 mm.; average, 6.0 mm. Width including the wings (not expanded), 2.8–3.6 mm.; average, 3.2 mm. Other characters not differing greatly from those described for *H. tessellatum.*

Bledius sp.

Last Larval Instar (Pl. LXIII, Fig. 20)

Length of body, 3.7–4.0 mm.; average, 3.9 mm. Width of head capsule, 0.54–0.60 mm.; average, 0.58 mm. Width of prothorax, 0.50–0.52 mm.; average, 0.51 mm. Length of head, with appendages and thorax, almost half as long as entire body. Head flattened, subcordate, attenuated posteriorly; thorax subcylindrical, each segment slightly enlarged in mediolateral portions. Abdomen subcylindrical, tapering from sixth abdominal segment anteriorly to first; last three tapering posteriorly. Color light yellow on body; head and setae darker.

Head subcordate; clypeus small; labrum projecting; mandibles simple, about as long as antennae, straight, apical ends curved; inner surface denticulated, more at distal end of mandibles; maxillae simple; cardo small; stipes fused with palpifer; galea absent; palpus small; labium distinct; mentum small; antennae distinct; scape large; flagellum composed of four segments; ocelli six on each side of head. Pubescence distinct. Y-shaped epicranial suture; light coloration, remainder of head dark.

Prothorax subovate; anterior and posterior angles present; dorsal plates covering most of surface; indentation medioanterior; remainder of anterior margin distinctly curved; lateral margin rounded;

posterior margin subtruncate. Intersegmental lines double posteriorly. Primary setae present, small; two on each plate anteromedian; three at lateral anterior angles; one at posterior lateral angle. Pubescence scarcely present, fine and sparse. Median suture just visible. Color, plates dark yellow, remainder light.

Mesothorax subquadrate; angles absent. Intersegmental lines double anteriorly and posteriorly. Dorsal plates present, removed from body margins; indentation medioanterior; remainder of margin curved; lateral sides curved; posterior margin with median indentation; remainder slightly curved. Primary setae very sparse; one large, median in each plate; one small anterolateral in each plate. Line of very small setae across posterior border of plates. Pubescence absent. Median suture slightly apparent. Color light yellow, plates slightly darker.

Metathorax subrectangular; angles absent. Intersegmental lines double. Dorsal plates present, covering less area than in other two segments; anterior indentation medioanterior, remainder of anterior margin slightly curved; lateral margins almost straight; posterior margin with rather deep medioposterior indentation, remainder distinctly curved. Primary setae few, one large in center of each plate; small setae; three on posterior margin of each plate. Pubescence absent. Median suture barely visible. Color yellow, plates darker.

Ventral aspect of thorax simple; coxal cavities lateral.

Prothoracic leg: coxa conical; wider at base than long; trochanter small, ring-shaped; femur twice longer than wide, cylindrical, tapering at each end just slightly, two pairs of primary setae on inside; tibia three times longer than wide, cylindrical, tapering at both ends; six primary setae on inside, none on outside. Tarsus three-jointed; first segment three times longer than wide, slightly tapering distally; five spines arranged near apical end; second segment short, conical; four spines toward distal end. Last segment almost perfect cone, small.

Meso- and metathoracic legs similar; variation in the pubescence; spines about the same.

Dorsal aspect of eight abdominal segments similar; form increasing in width from first to sixth segment; slight tapering in seventh, distinct in the eighth and ninth segments. Form and arrangement of dorsal plates variable, all wider than long; plates arranged symmetrically on segment; median indentation visible in anterior mar-

gins of the first seven segments, in posterior of all eight. Mediolateral protuberances present, each with four primary setae. Ninth segment small; no dorsal plate; urogomphi small, solid. Tenth segment apparently absent. General small, fine pubescence on most parts. Color light, except on median portions of plates, which are yellow. Primary setae on plates variable.

Ventral aspect of all abdominal segments similar, simple; setae and plates absent.

Spiracles on first eight abdominal segments, annular.

Pupa (Pl. LXIV, Fig. 24)

Typical exarate pupa. Total length, 3.4–4.2 mm.; average, 3.8 mm. Width including wings (not extended), 1.2 -2.0 mm.; average, 1.6 mm. (Measurements taken from preserved materials.) Color of body white to light cream. Eyes distinctly brownish. Setae on lateral portions of each abdominal segment, varying from 1 to 2; none apparent on dorsal surfaces of body. Pubescence obvious on prothorax, coarse; remainder with a very fine clothing of hair, scarcely discernible. Head and mouth parts resembling those of adult, head bending forward. Abdomen with seven segments. Pro- and mesothoracic legs folded under thorax; fold occurring at femorotibial joint; metathoracic legs partly folded. Length of pupal stage 5–10 days.

SUMMARY

1. Certain fresh-water lakes possess an assemblage of sand-burrowing insects on the narrow inner-beach or barrier-beach bars, and on sand-spits.

2. This fauna, comprising (1) true burrowers and (2) visitors, is made up of representatives of the following families of the order Coleoptera: Homophronidae, Carabidae, Heteroceridae, Hydrophilidae, Staphylinidae, Lampyridae, and Mordellidae.

3. Adult burrowing beetles are more numerous in the early part of the summer season; the immature forms appear to be more prevalent in the latter part.

4. Each species produces a characteristic burrow. Larvae and adults of the same species make different burrows.

5. Plankton materials on and in the beach serve as food for these burrowing insects. Those maintained in the laboratory for

as long as ten months fed actively on plankton collected from the surface waters of the lake.

6. The entire life cycle is passed in the burrows. There are five larval instars, each fitted morphologically to inner-beach burrowing. The pupal stage is passed in a widened portion of the burrow.

7. The adults of all burrowing species overwinter in the beach, deposit their eggs the following spring, and die off during the summer.

8. Immature stages of the insects involved are illustrated and described in detail for the first time.

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Denton, Texas.

LITERATURE CITED

(The complete bibliography employed in this work is on file in the office of the Graduate School, University of Michigan.)

Andrews, A. W. 1923. The Coleoptera of the Shiras Expedition to Whitefish Point, Chippewa County, Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 1 (1921) : 293–390.

Claycomb, G. B. 1919. Popular and Practical Entomology: Notes on the Habits of Heterocerus Beetles. Can. Entomol., 51 : 25, 1 pl.

Dury, Charles. 1902. A Revised List of the Coleoptera Observed near Cincinnati, Ohio, with Notes on Localities. Bibliographical References and Descriptions of Six New Species. Journ. Cin. Soc. Nat. Hist., 20 : 1–196, 6 figs.

Klunzinger, C. B. 1906. Über einen Schlummkafer (*Heterocerus*) u. seine Entwicklung in einem Puppengehause. Verh. Deutsch. Zool. Gesell., 16 : 218–222, 1 fig.

Wickham, H. F. 1903. The Beetles of an Oregon Beach. Ottawa Nat., 17 : 49–52.

Williams, F. X., and Hungerford, H. B. 1911. Notes on Coleoptera from Western Kansas. Ent. News, 25: 1–9.

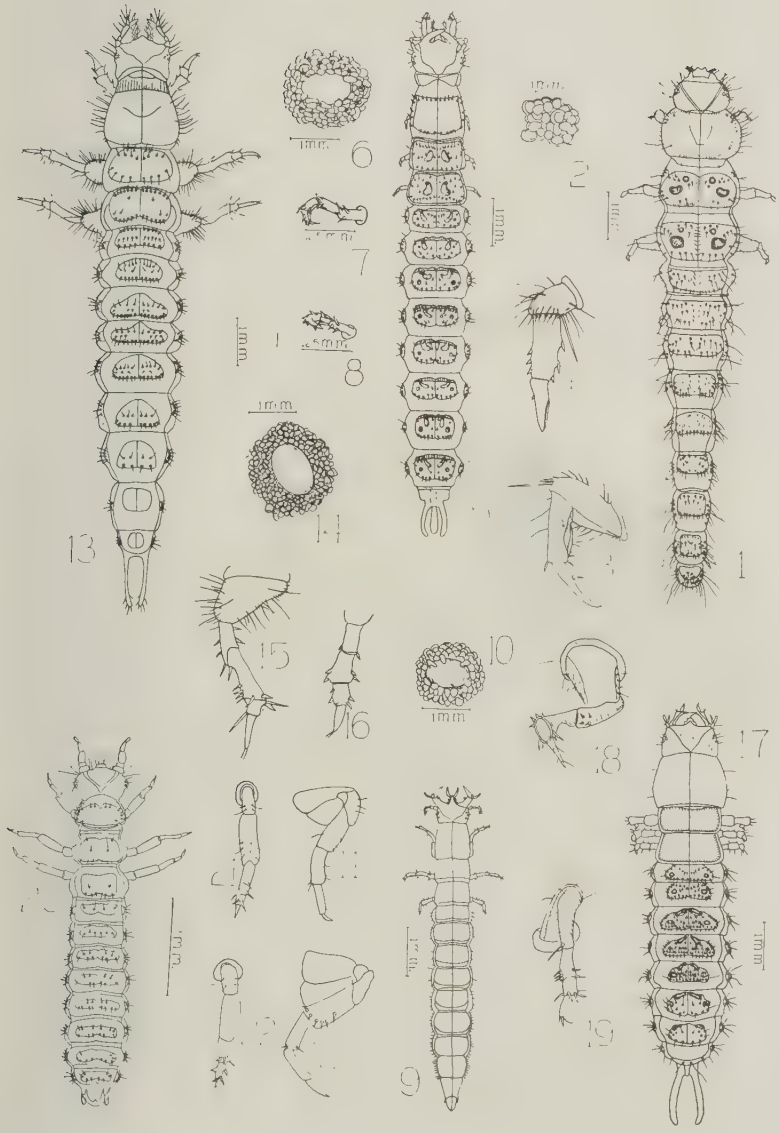
EXPLANATION OF PLATE LXIII

FIG.

1. Fifth larval instar of *Heterocerus auromicans*
2. Group of eggs of *H. auromicans*
3. Larval prothoracic leg of *H. auromicans*
4. Larval metathoracic leg of *H. auromicans*
5. Fifth larval instar of *Bembidion confusum*
6. Egg of *B. confusum*, with sand capsule
7. Larval prothoracic leg of *B. confusum*
8. Larval metathoracic leg of *B. confusum*
9. Fifth larval instar of *Dyschirius sphaericollis*
10. Egg of *D. sphaericollis*, with sand capsule
11. Larval prothoracic leg of *D. sphaericollis*
12. Larval metathoracic leg of *D. sphaericollis*
13. Fifth larval instar of *Homophron tessellatum*
14. Egg of *H. tessellatum*, with sand capsule
15. Larval prothoracic leg of *H. tessellatum*
16. Larval metathoracic leg of *H. tessellatum*
17. Fifth larval instar of *Homophron americanum*
18. Larval prothoracic leg of *H. americanum*
19. Larval metathoracic leg of *H. americanum*
20. Larva of *Bledius sp.*
21. Larval prothoracic leg of *Bledius sp.*
22. Larval metathoracic leg of *Bledius sp.*

NOTE — Additional drawings, which could not be published here, are on file in the office of the Graduate School, University of Michigan.

PLATE LXIII

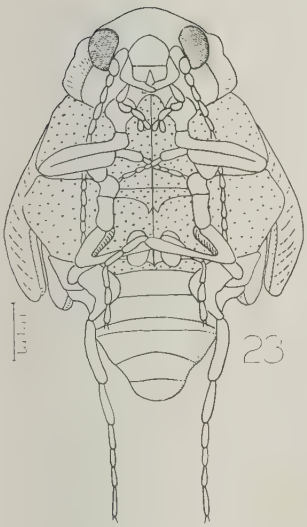


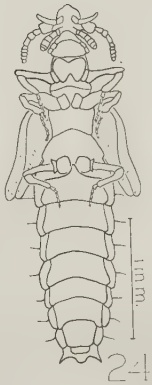
EXPLANATION OF PLATE LXIV

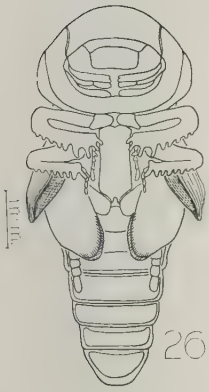
FIG.

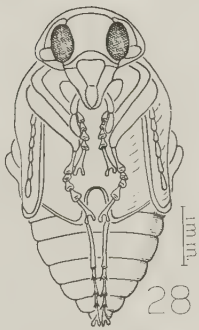
23. Pupa of *Homophron tessellatum*, ventral view
24. Pupa of *Bledius sp.*, ventral view
25. Pupa of *Dyschirius sphaericollis*, ventral view
26. Pupa of *Heterocerus auromicans*, ventral view
27. Pupa of *Homophron americanum*, ventral view
28. Pupa of *Bembidion confusum*, ventral view

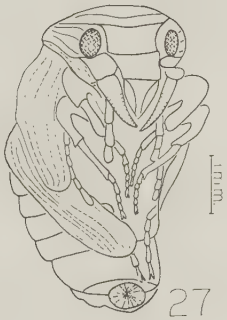
PLATE LXIV











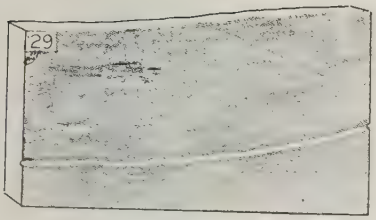
EXPLANATION OF PLATE LXV

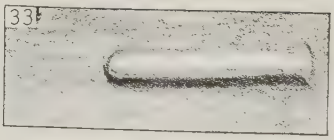
Diagrams of insect burrows in sand

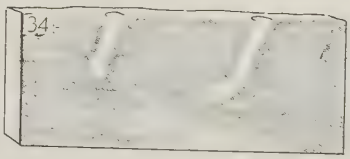
FIG.

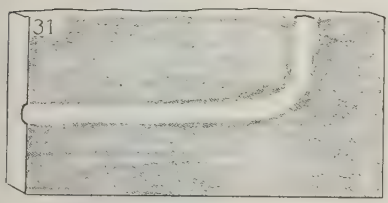
29. *Dyschirius nigripes* adult
30. *Dyschirius longulus* adult
31. *Agonoderus pallipes* adult
32. *Homophron tessellatum* adult; vertical section through burrow
33. *Homophron tessellatum* adult; surface view
34. *Bembidion confusum* adult
35. *Homophron americanum* adult; surface view
36. *Homophron americanum* adult; vertical section

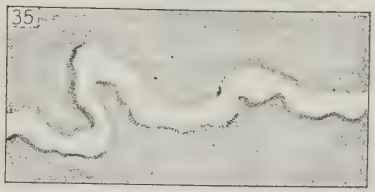
PLATE LXV

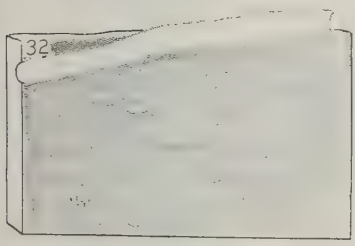


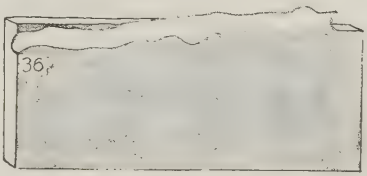












EXPLANATION OF PLATE LXVI

Diagrams of insect burrows in sand; surface views

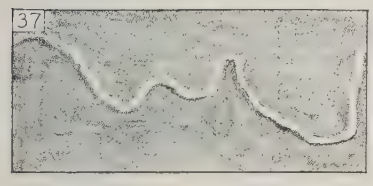
FIG.

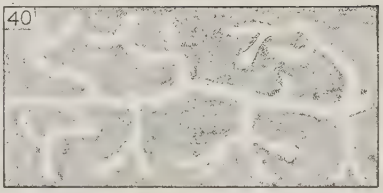
37. *Bembidion confusum* larva
38. *Dyschirius sphaericollis* adult
39. *Dyschirius sphaericollis* larva

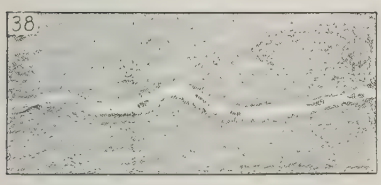
FIG.

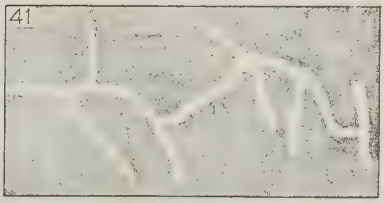
40. *Homophron tessellatum* larva
41. *Homophron americanum* larva
42. *Heterocerus auromicans* larva
43. *Heterocerus auromicans* adult

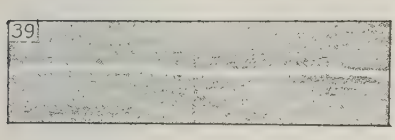
PLATE LXVI

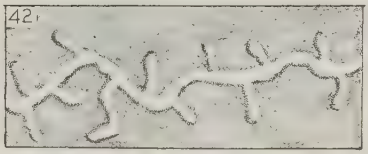


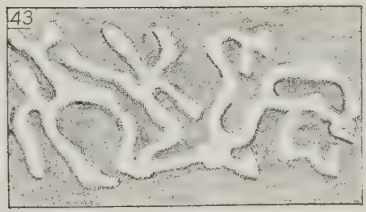












A MORPHOLOGICAL STUDY OF THE RESPIRATORY SYSTEM IN VARIOUS LARVAL INSTARS OF *STENELMIS SULCATUS* BLATCHLEY (DRYOPIDAE; COLEOPTERA) *

MARIE E. CIMINI SUSSKIND

STENELMIS SULCATUS was described by Blatchley (1910) from specimens found in Lake Maxinkukee, Marshall County, Indiana. This insect is unusual in two respects, namely, type of habitat and possession of certain uncommon morphological structures in the larval stage. The few records so far made for it suggest that it is probably restricted to marl lakes, in which it passes its life, seldom, if ever, coming to the surface for air. Larvae and adults occur in the interstices of marl concretions which, in rare instances, abound in such lakes, or in the common accumulations of marl on shells of mussels or other objects. The insect is well adapted for life in such a situation because of its strong negative reaction to light and its positive thigmotaxis. At the same time, practically buried as it is in the marl accumulations, it is closely associated with the numerous Algae, some of which build the concretions and give off oxygen in their photosynthetic activities. Its morphological interest is presented by the larval stage, which possesses an uncommon set of structures. These are limited to a relatively small group of insects, namely, those of the families Parnidae and Dryopidae, and are sometimes referred to as "caudal gills." In *Stenelmis sulcatus* they consist of three tufts of filaments at the posterior end of the body which are protrusible through the tip of the last abdominal segment. Under certain conditions, such as abnormal increase in temperature of water, exposure to light, high carbon dioxide tension, or low oxygen tension, the larvae rhythmically extend and retract these caudal filaments. Sometimes the rhythm is rapid, sometimes slow, depending upon the conditions to which the larvae are subjected. If, however, several larvae are allowed to rest in a dish of water, they curl up together into a mass,

* Contribution from the Department of Zoölogy, University of Michigan.

and their caudal filaments remain retracted as long as the larvae are left undisturbed. During this quiescent period the larvae are carrying on respiration, apparently without the aid of the caudal filaments. When larvae are subjected to abnormal conditions, the retraction and the extension of the filaments appear, in a measure, to be a response to an irritability which results in a rapid locomotion, and the filaments and the posterior part of the abdomen are used in a way that suggests the rapid backward locomotion of a crayfish. This response is most pronounced when the larvae are submerged in acid, alcohol, warm water, or other medium which makes them extremely uncomfortable. Abnormal carbon dioxide or oxygen tensions do not bring forth so active a response.

Since the most unusual features of *Stenelmis sulcatus* are presented by the larva, only that stage was studied during this investigation. A comparison was made of the morphology and physiology of the respiratory system in three larval instars. The problems that first presented themselves were: (1) Are the larvae catching and using oxygen directly as it is given off by the marl-forming Algae or do they use the dissolved oxygen of the surrounding water? (2) Is the respiratory system an open or a closed one? (3) Do the caudal filaments have a respiratory function?

Acknowledgments

The writer wishes to express her indebtedness to Professor Paul S. Welch, who guided this investigation; to Mr. Marion R. Raymond, who brought in materials from the field during two winters; and to various other persons who gave valuable advice and assistance.

Methods

The uninterrupted progress of this investigation over a period of two years was facilitated by the presence of a rich bed of marl concretions in Bass Lake, eighteen miles northwest of Ann Arbor, Michigan. These concretions, containing all stages of the insect except the pupa, can be obtained throughout the year.

culture

Marl concretions from Bass Lake commonly contain life-history stages of *Stenelmis sulcatus*. Sometimes as many as one hundred

larvae of various instars may be found in a medium-sized concretion. Laboratory culture is relatively simple. Concretions may be kept for weeks in an aquarium filled with constantly aërated water at ordinary room temperatures and in a room to which sunlight is admitted for maintenance of the Algae. One culture was maintained for a year under these simple conditions, and during that time all larval instars as well as adults were present. Therefore, eggs are apparently laid throughout the year under these conditions, although attempts to find them among the marl particles were unsuccessful.

TECHNIC

Dissecting Instruments

Stenelmis sulcatus is about 1 mm. in length in its first larval instar and about 5.5 mm. in its last larval instar. It was necessary, therefore, to devise instruments small enough for microscopic dissection.

Gross dissections of the larger larvae were made under the 40-mm. objective of the compound microscope by means of small pieces of a safety razor blade attached to mechanical fingers clamped to the microscope stage. For more delicate dissections fine scalpels were constructed by grinding the points of steel sewing needles to a sharp cutting edge and fitting them into handles.

All dissections were made by partly filling the cavity of a depression slide with paraffin. The larva was held in place in this paraffin by means of one insect "minuten" pin, since the extremely small size of the larva made it impossible to fasten it down at more than one point at a time. The free portion was carefully dissected by using both hands, each supplied with a fine scalpel, or by the use of mechanical fingers.

Phenol Preparations

The efficacy of phenol as a clearing agent suggested its use in a preliminary examination of the larvae before dissection was begun. When living first-instar larvae, which are not so heavily chitinized as the older ones, are placed in phenol, the main tracheal trunks and some of the smaller tracheae are easily visible through the body wall. Therefore, phenol was used in studying the gross aspects of the tracheal system of the first larval instar and in clearing tissues surrounding a given structure. It was especially useful in observing the structure of spiracles and spiracular vestibules.

Glycerine Preparations

Wahl (1900) found glycerine useful in his study of the respiratory system of *Eristalis tenax* L. In accordance with this suggestion, living larvae were submerged in glycerine until the tissues were completely permeated with it. Upon dissection the tracheae appeared silvery white in their glycerine bath, owing to the gas which remained imprisoned within them. This proved an invaluable method for the study of larger tracheal tubes in the older larvae.

Stained Oil Preparations

To study the minute branches and tracheoles, a third method was required. It was found that, when living larvae are submerged in kerosene, xylol, or benzol, these liquids gradually fill the tracheae, rendering them translucent, but that, if these liquids are first stained with Sudan III, the tracheae become colored a decided pink due, according to Hacker (1925), to the adherence of the Sudan III to their walls, so that even the tracheoles are readily visible with the highest magnification of the compound microscope. Staining of the oils was done according to Hacker's method by shaking a slight excess of Sudan III into the liquid and gently heating it. Benzol was the most effective, and only a small quantity was prepared at a time; fresh solutions were made as needed.

Morphology of Respiratory System

first larval instar

Ventral Aspect

Main tracheal trunks

The main tracheal trunks, seen from the ventral surface (Pl. LXVII, Fig. 1 *mtt*), consist of a pair of large lateral tubes, which gradually become smaller in diameter at the anterior end and, on entering the head (*ht*), divide into numerous branches, which supply the head capsule and the organs within it. At the posterior end and in the region of the last abdominal segment each trunk is divided into two branches, the most lateral of which (*mdt*) extends posteriorly for a short distance, then bends mesad to form an ascending loop, which extends into the body, coming to lie dorsad to the intestine, where it bends once more to form a short descending loop. Here it meets the descending loop from the opposite trunk, and together they supply

the middorsal tuft of the caudal filaments. The second and innermost branch of the main trunk (*lt*) extends posteriorly as a single tube at first, finally dividing into two branches, which remain separated except at the tip, where they approximate to supply the lateral tuft of caudal filaments. Thus each tuft is supplied by two branches of the main tracheal trunks.

Caudal filaments

The caudal filaments appear to be evaginations from the main tracheal trunks, at the posterior ends of which they form, in all, three tufts (Pl. LXVII, Fig. 1 *lt mdt*). The middorsal tuft is the largest and lies dorsad to the intestine. It consists of 47–72 filaments, average 55. The lateral tufts lie ventrad to, and at either side of, the intestine and consist of 24–49 filaments, average 35. The wall of the filament appears to consist of a relatively thick chitinous outer layer and an inner, basement membrane. In the first instar the filaments vary in length from 102 to 151 μ inclusive and have a diameter of 4.8 μ at the proximal end and 2.3 μ at the tip. Each is supplied with two tracheoles from the main trunk which twist spirally around each other and end blindly at the tip.

Transverse connectives

Transverse connectives (Pl. LXVII, Fig. 1 *tc*) extend from one main, longitudinal trunk to the other on the ventral side and, though there are always nine in the first larval instar, the number of branches given off by them to other structures varies somewhat. In one larva a connective in the region of the second abdominal segment gives off two branches to the ganglion in that region, whereas in another larva of the same instar the connective in the same region has three or four branches.

Ganglionic and nerve-cord tracheae

The ganglionic tracheae (Pl. LXVII, Fig. 1 *tns*) are given off by the transverse connectives sometimes from their upper and sometimes from their lower side in the midventral region. Two to four ganglionic tracheae develop from each transverse connective and they, in turn, give off one to three smaller branches to the nerve cord.

Ventral body-wall tracheae

Ventral body-wall tracheae (Pl. LXVII, Fig. 1 *vbw*) are given off from the two main trunks throughout their entire length. These tracheae are not bilaterally symmetrical. In one larva the left trunk may supply a greater number than the right trunk, whereas in another larva the reverse is true. However, all these branches send off tracheoles into the ventral body wall, where the latter anastomose and form a network which supplies the entire ventral side.

Leg tracheae

Tracheae to the legs are likewise supplied by the main tracheal trunks (Pl. LXVII, Fig. 1 l_1 l_2 l_4). Here again there is a variation in the number of branches. The first pair, being the largest, is supplied with more branches than are the others. However, the number of branches sent off to the legs on the right side does not always agree with the number sent off to those on the left.

Head tracheae

In the previous discussion of the morphology of the main tracheal trunks it was pointed out that at their anterior ends they send off numerous branches to the head. A ventral view reveals only the branches to the head capsule and to the mouth parts. These branches are variable in number, but are quite simple and need no description. The remainder of the head tracheation is discussed below.

Dorsal Aspect

Main tracheal trunks

From a dorsal view (Pl. LXVII, Fig. 2) the main trunks present the same picture as that on the ventral side, except that the dorsal side, having no transverse connectives, reveals the small ectal protrusions (Pl. LXVII, Fig. 2 *ep*) which represent the beginnings of evaginations, from which in older instars the spiracular tracheae develop.

Visceral tracheae

The visceral tracheae are given off from the dorsomesal side of each of the main trunks, forming pairs which are more or less bilaterally symmetrical. In the head region the first two pairs are relatively thick tubes (Pl. LXVII, Fig. 2 vt_1 vt_2), which break up into smaller

branches on entering the alimentary tract. A third pair (vt_3) given off farther down, just at the beginning of the prothorax, also sends off smaller branches into the wall of the alimentary tract. The fourth pair (vt_4) takes its origin in the region of the second abdominal segment and, proceeding anteriorly, sends off branches to the intestine, finally breaking up into from five to seven branches, all entering the "gastric mill" located in the prothorax. The fifth pair (vt_5) takes its origin in the region of the third abdominal segment, extending cephalad to supply that portion of the alimentary tract in the first and second abdominal segments. The sixth pair (vt_6) is the most complex. Taking its origin from the main trunks in the region of the fifth abdominal segment, each component of the pair, after a short mesad course, divides into two branches, one of which goes cephalad, sending off smaller branches which supply that part of the intestine located in the third and fourth abdominal segments and branches which supply other visceral organs in the same region, whereas, the second branch extends caudad, also breaking up into smaller branches which supply the portion of intestine in the sixth abdominal segment. Each component of the seventh pair (vt_7), taking its origin in the region of the eighth abdominal segment, likewise divides into two branches, one of which goes cephalad to supply the intestine in the seventh segment and the other caudad to supply the intestine in the region of the eighth and ninth segments.

In the first larval instar the paired visceral tracheae always number seven and always take their origin from the same region of the main trunks. However, the number of smaller branches which they give off to the wall of the digestive tube or of other visceral organs varies a little in larvae of the same instar.

Dorsal body-wall tracheae

Dorsal body-wall tracheae arise from the main tracheal trunks on their lateral faces and are similar in form to those previously described which supply the ventral body wall.

Ocellar tracheae

Ocellar tracheae (Pl. LXVII, Fig. 2 *ot*) arise from one of the branches of the main trunks which supply the head. At its distal end the branch divides into several smaller branches which, in turn, resemble the recurved fingers of a hand. These curved, finger-like

tracheae terminate in the region of the ocelli, and there are never fewer than four and never more than five in each group. They are usually bilaterally symmetrical, the number being the same for both groups of ocelli in the same larva.

Antennal tracheae

Antennal tracheae (Pl. LXVII, Fig. 2 *at*) are likewise given off from one of the branches of the main tracheal trunks supplying the head. Usually two, and sometimes three, tracheae supply each antenna; these are quite simple and need no further description.

MORPHOLOGY OF AN INTERMEDIATE LARVAL INSTAR

The intermediate larval instar here described is, in all probability, the third instar although, owing to the rather unsatisfactory results of breeding experiments, the writer does not wish to state definitely that it is the third. Consequently the instar studied throughout this investigation will be referred to as an intermediate larval instar. The larva in question is about 3 mm. long and shows a stage of development midway between that of the first instar and that of the last.

Ventral Aspect

Main tracheal trunks

In this instar each main tracheal trunk (Pl. LXVIII, Figs. 1 2) possesses a definite form having a well-defined ental bend between each two of the developing spiracular tracheae. At their anterior and posterior ends no further developmental changes occur in the main trunks except for a more regular curvature of the branches leading to the caudal tufts. Also, the trunks throughout their entire length have a greater diameter than those in the first instar. The evaginations of the spiracular tracheae (Pl. LXVIII, Fig. 1 *ste*) which, in the first instar, were irregular ectal protrusions (Pl. LXVII, Fig. 2 *ep*), now take on a definite form and position; two pairs of them are always present in the thorax and eight pairs in the abdomen.

Spiracular tracheae

The spiracular trachea has its origin from the main trunk at about the level of the anterior end of the body segment in which the spiracle is to develop in the last larval instar. In this intermediate instar the

spiracular tracheae have developed about one half of their final extent, ending as blind tubes in the body cavity. As development progresses they proceed in a ventro-latero-ectal direction, toward the destined position of the spiracle, midway between the intersegmental grooves.

Transverse connectives

The transverse connectives of this intermediate instar are similar in form to those of the first instar except that, whereas the latter had a constant number of nine connectives, in the former (Pl. LXVIII, Fig. 2 *tns*) the number has increased to eleven. This number remains constant throughout the rest of the larval stage of the insect.

Ganglionic and nerve-cord tracheae

Similarly, the ganglionic and nerve-cord tracheae are of the same form as those already described for the first instar. Furthermore, there are eleven pairs, a number that corresponds to the number of transverse connectives, whereas in the first instar the number of paired ganglionic tracheae corresponds to the number of transverse connectives present at that stage.

Caudal filaments

The tufts of caudal filaments present the same general appearance in this intermediate instar as they do in the first. The average number of filaments in each tuft is approximately the same. The length and the diameter of the filaments, however, have increased in proportion to the greater length of the larva itself. Associated with the caudal filaments, a new structure has made its appearance in the intermediate instar. This structure is here called the "caudal chamber" because of its position and nature. Its morphology will be discussed later under a separate heading. Tracheae of all other structures seen in the ventral view of the respiratory system are comparable to those for the first instar described above; consequently, no further description is needed.

Dorsal Aspect

The dorsal aspect of the respiratory system of the intermediate larval instar is essentially like that of the first instar in every respect except for the visceral tracheae and those advances in development already described in the discussion of the ventral aspect.

The visceral tracheae do not differ fundamentally in structure from those in the first instar. There is, however, an increase in the number of branches supplying the visceral organs (Pl. LXVIII, Fig. 1 vt_1–vt_{11}), which are larger and more advanced in development than they are in the first instar.

MORPHOLOGY OF LAST LARVAL INSTAR

In the last larval instar (Pl. LXIX; Pl. LXX, Fig. 1) the respiratory system is in every respect similar in structure to that of the intermediate instar, except that the spiracular tracheae are now completely developed and that the spiracles make their appearance. A detailed description of the spiracles and their tracheae will be given later under a separate heading.

MORPHOLOGY OF FILAMENTS AND CAUDAL CHAMBER

Caudal Filaments

As previously stated, the filaments are aggregated into three tufts. There appears to be no increase in their number as the larva develops, but there is an appreciable increase in size. Their length in the last instar varies from 464 to 608 μ. The diameter of each filament in this instar is about 6.2 μ at the proximal end and 2.7 μ at the tip. Likewise, the layer of chitin is relatively much thicker in the filaments of the last instar larvae. However, the number of tracheoles that supply each filament remains the same. Two tracheoles, characteristically twisted about each other, are in each filament of all instars.

Caudal Chamber

The histological structure of the wall of the caudal chamber is apparently similar to that of the filaments, with the exception of the chitinous layer, which is relatively thinner. The caudal chamber completely invests the main tracheal trunks and the intestine in that region; its wall lies close to the body wall. Branches from the main trunks supply the wall of the caudal chamber on its inner face. In the wall they break up into a network of tracheoles, which completely ramify the inner layers. Thus the caudal chamber wall furnishes a relatively large surface of comparatively thin tissue, through which diffusion of gases may readily take place.

At the posterior end, in the region of the caudal tufts, the chamber

wall is divided into three separate tubelike parts, each of which envelops the main tracheal trunks at their distal ends. Each of these parts, as well as the remainder of the caudal chamber wall, is capable of shortening, by forming a series of folds, when the caudal filaments are retracted into the body. The tissue that composes the wall is, therefore, fairly flexible owing to its reduced chitinization. This condition makes it possible for the caudal tufts to be extended and retracted with an ease that would not be possible if the wall of the caudal chamber were rigid.

Apparently, that rhythmic extension and retraction of the tufts which occurs under certain conditions is not due to muscles extending from the body wall to the wall of the caudal chamber, since thus far no muscles have been found that are in any way connected with the caudal chamber or with that part of each tracheal trunk which lies within the chamber. It does not seem likely that muscles operating the mechanism of the caudal tufts, if present, would be so minute as to escape detection. However, this subject requires further investigation before a definite statement can be made concerning the method of action of these caudal structures.

MORPHOLOGY OF SPIRACLES

Position

It has already been stated that the spiracles are not found until the larva attains its last instar. There are, in all, ten pairs of spiracles, two in the thorax and eight in the abdomen. Thoracic spiracles are located in the mesothorax and metathorax. Abdominal spiracles are located in the first eight segments. The position of the spiracles is a ventrolateral one. The "ears" of the spiracles protrude outside the body wall midway in the segment and on the ventral portion of the pleura, so that, if a larva is crawling on a wet surface, the apertures of the spiracles are in contact with that surface.

Structure

Each spiracle is surrounded by an outer rim (Pl. LXX, Fig. 2 *or*), which is more highly chitinized than the rest. The aperture of the spiracle is closed by two lightly chitinized membranes (Pl. LXX, Fig. 2 *mem*), which prevent the entrance of water into the tubes and probably act as diffusion membranes. These membranes are attached all along their outer edge to the periphery of the spiracular aperture.

Across the center of the aperture the membranes meet in a straight line parallel to the long axis of the body. These median edges are fused to each other, the straight line being, to all appearances, a suture marking their point of juncture. Under no circumstances do these membranes pull apart to form an opening which would communicate with the tracheal tubes, nor are they provided with muscles or levers which might serve to open and close them.

Entad from the aperture is a short vestibule, the wall of which is made up largely of cuticle. This vestibule leads into the spiracular trachea, where the chitinous lining is modified by the presence of taenidia. The spiracular trachea enters the main trunk at the position already described. Morphologically, the tracheal system of the last instar larva is an open one, except these membranes in the openings of the spiracles.

Digestive System and Relation to Caudal Chamber and Filaments

gastric mill

The mouth opens into a simple, thin-walled tube, which gradually grows broader as it reaches the posterior end of the prothorax. At this point two layers of short longitudinal bundles of muscle fibers are laid end to end, forming a curious structure that suggests a gastric mill. This gastric mill usually contains numerous diatoms, but occasionally rotifers, microcrustacea, and particles of marl also occur in it. Its structure is the same in all larval instars. Its size, however, increases proportionately with the size of the larva.

intestine

From the gastric mill the intestine continues as a thin-walled tube, which gradually tapers as it approaches the anal aperture. Muscles and branches of the tracheal system serve to hold it at approximately the middle of the body.

anal aperture

Throughout the development of the larva no changes occur in the digestive system except for the relation between the anal aperture and the caudal chamber when the latter appears. It has been shown that in the first instar (Pl. LXVII, Figs. 1–2) the caudal filaments are

grouped in tufts about the posterior ends of the main tracheal trunks. The intestine and the anal aperture in this instar are not associated with the caudal filaments. At the extreme end of the last abdominal segment the sternum is provided with a shieldlike sclerite, which is hinged at its cephalic end and is free all the way to the tip of the abdomen, and is thus enabled to open and close that part of the abdomen when the tufts are extended and retracted. Therefore, in this instar the anal aperture opens to the outside independently of the caudal filaments when the sclerite is open. However, when in later instars the caudal chamber is developed, the tufts and the anal aperture become associated with it. The posterior end of the intestine becomes enveloped by the wall of the caudal chamber, and the anal aperture takes its position in the middorsal tuft, the filaments of which completely surround the opening. A peculiar phenomenon sometimes occurs in larvae that have the caudal chamber. If living larvae are dropped into concentrated sulphuric acid or some other extremely injurious liquid, they struggle violently and ultimately die. This struggle causes the intestine to break just above the place of attachment of the caudal chamber, and the lowermost part of the intestine becomes extraverted through the anal aperture. This brief description of the alimentary tract has been included in the discussion of the respiratory system because of the relationship between them in the older instars.

General Discussion of Respiratory System

It is seen from this study of *Stenelmis sulcatus* that the larval respiratory system is essentially a terrestrial one which has become secondarily modified for an aquatic habitat. There is, on the whole, no unusual specialization in the tracheal system. There are typically ten pairs of spiracles, a number which, according to MacGillivray (1923), represents the most primitive condition, at least in the higher forms, in which the tracheal system is fused into a connected whole and from which many specializations have developed that involve the loss of some or all of the spiracles. The caudal chamber appears to be a specialized structure but, to judge by its morphology, it does not seem to be respiratory in function in the same sense as is the respiratory chamber, described by Kuster (1933), which is found in *Stratiomyia* and *Odontomyia* larvae and into which the tracheal system opens by means of a pair of posterior spiracles. The caudal filaments are

true chitinous filaments supplied with tracheoles and are a direct continuation of the tracheal system. These filaments must not be confused with those hairlike structures at the terminal end of the abdomen in the larval forms of some other insects such as "*Stratiomys*" *chameleon*, which Henneguy (1904) and Berlese (1909) describe as "rigid, chitinous filaments," and which Wahl (1900) calls "bristles" when referring to similar structures in *Eristalis tenax* L., and which Dunavan (1929), working with *Eristalis arbustorum* L., calls "feather-like setae." In all these forms the structures are essentially hairlike, and those of stratiomyiad larvae have been adequately described by Kuster, who calls them "plumose hairs."

The terminology used in describing the tracheal system of *Stenelmis sulcatus* follows, so far as possible, that of Kennedy (1922) whenever homologous parts are being described and when the homology of the tracheae is obvious, which is true of the larger tubes. In designating some of the lesser tubes names have been adopted from the structures which the tracheae in question supply. This system has been resorted to because, up to the present time, Kennedy's work, already mentioned, still remains the only attempt to homologize the various parts of the tracheal system of insects. This is true in spite of the large amount of work that has been done on the respiratory system in the present century, to say nothing of the work that preceded 1900. To the investigators in this field one might here add several others merely to give the reader some idea of the wide diversity of the groups studied. Thus Miall and Hammond (1900) studied the morphology of the harlequin fly; MacGillivray (1903), the aquatic Chrysomelidae; Börner (1909), the Ephemerida; Böving (1910), the larvae of Donaciinae; Brocher (1911) and Alt (1912), Dytiscus; D'Orchymont (1913), the Hydrophilidae; and the list could be expanded to include nearly all the groups of insects. Therefore, the necessity for an extensive work on homology of the respiratory system is quite obviously an urgent one, and Kennedy's work, though it is splendid so far as it goes, is after all only a beginning.

Summary

1. Both larvae and adults of *Stenelmis sulcatus* occur in marl concretions and are permanently submerged, never coming to the surface for air.

2. The larval tracheal system has fewer branches in the first instar than in all older larvae.

3. In the first larval instar neither spiracles nor spiracular tracheae are present.

4. The intermediate instar studied has spiracular tracheae, which are about half developed.

5. Last instar larvae have completely developed spiracular tracheae and ten pairs of spiracles. The spiracular apertures are permanently closed by weakly chitinized membranes.

6. Larvae of all instars possess three tufts of caudal filaments at the posterior end of the main tracheal trunks. These tufts are protrusible through the tip of the last abdominal segment.

7. Intermediate and last instar larvae possess a caudal chamber associated with the caudal filaments.

8. The tracheal system of all larval instars is a closed one.

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LITERATURE CITED

Alt, W. 1912. Über das Respirationssystem von *Dytiscus marginalis* L. Zeit. wiss. Zool., 99: 354–413.

—— 1912. Ueber das Respirationssystem der Larva von *Dytiscus marginalis* L. *Ibid.*, 99: 414–443.

Berlese, Antonio. 1909. Gli Insetti. Vol. I. 1004 pages. Società Editrice Libraria, Milano.

Blatchley, W. S. 1910. An Illustrated Descriptive Catalogue of the Coleoptera or Beetles Known to Occur in Indiana. 1386 pages. Nature Publishing Co., Indianapolis.

Börner, C. 1909. Die Tracheenkiemen der Ephemeriden. Zool. Anz., 33: 806–823.

Böving, A. G. 1910. Natural History of Larvae of the Donaciinae. Int. Rev. d. ges. Hydrobiol. u. Hydrogr., Suppl. I: 1–108.

Brocher, F. 1911. Étude anatomique et physiologique du système respiratoire chez les larves du genre Dytiscus. Ann. Biol. Lac., 5: 128–147.

Dunavan, David. 1929. A Study of Respiration and Respiratory Organs of the Rat-tailed Maggot, *Eristalis arbustorum* L. (Diptera: Syrphidae). Ann. Ent. Soc. Am., 22: 731–753.

Hacker, H. P. 1925. How Oil Kills Anopheline Larvae. Federated Malay States Malaria Bureau Reports, 3: 1–62.

Henneguy, L. Félix. 1904. Les Insectes, morphologie — reproduction — embrogénie. Masson et Cie, Paris. 804 pages.

Kennedy, C. H. 1922. The Homologies of the Tracheal Branches in the Respiratory System of Insects. Ohio Journ. Sci., 22 : 84–90.

Kuster, Kimber Cleaver. 1934. A Study of the General Biology, Morphology of the Respiratory System, and Respiration of Certain Aquatic *Stratiomyia* and *Odontomyia* Larvae (Diptera). Pap. Mich. Acad. Sci., Arts and Letters, 19 (1933) : 605–658.

MacGillivray, A. D. 1903. Aquatic Chrysomelidae. *In* "Aquatic Insects of New York State." Bull. New York State Mus., 68 : 288–327.

Miall, L. C., and Hammond, A. R. 1900. The Structure and Life-History of the Harlequin-fly. Oxford. 196 pages.

Orchymont, A. d'. 1913. Contribution à l'étude des larves hydrophiles. Ann. Biol. Soc., 6 : 180–214.

Wahl, Bruno. 1900. Über das Tracheensystem und die Imaginalscheiben der Larve von *Eristalis tenax* L. Arbeiten aus dem Zoologischen Institut der Universität Wien u. d. Zoologischen Station in Triest, 12 : 45–98.

ABBREVIATIONS USED IN PLATES

I–II — mesothoracic and metathoracic spiracles
1–8 — abdominal spiracles
an — anus
at — antennal tracheae
bw — body wall
bwt — body-wall tracheae
cc — caudal chamber
cct — caudal-chamber tracheae
cw — chitinous wall of caudal filament
dbw — dorsal body-wall tracheae
e — "ear" of spiracle
et, ot — ocellar tracheae
gm — gastric mill
h — head
ht — head tracheae
int — intestine
l_1, l_2, l_3 — leg tracheae
lt — lateral tuft of caudal filaments
ltb — branch of main tracheal trunk supplying lateral tuft of filaments
m — "mouth" or aperture of spiracle
mdt — middorsal tuft of caudal filaments
mdbt — branch of main tracheal trunk supplying middorsal tuft of filaments
mem — membranes closing spiracular aperture
mes — mesothorax
met — metathorax
mtt — main tracheal trunk
or — strongly chitinized outer rim of spiracle
pro — prothorax
sp — spiracle
st — spiracular trachea
ste — spiracular trachea evagination
tc — transverse connectives
tns_1–tns_{11} — ganglionic and nerve-cord tracheae
tr — tracheole
v — spiracular vestibule
vbw — ventral body-wall tracheae
vt_1–vt_{11} — visceral tracheae supplying digestive system

EXPLANATION OF PLATE LXVII

FIG. 1. Ventral aspect of respiratory system of first instar larva

FIG. 2. Dorsal aspect of respiratory system and its relation to the digestive tract. First instar larva. Actual number of caudal filaments more than twice the number represented

PLATE LXVII

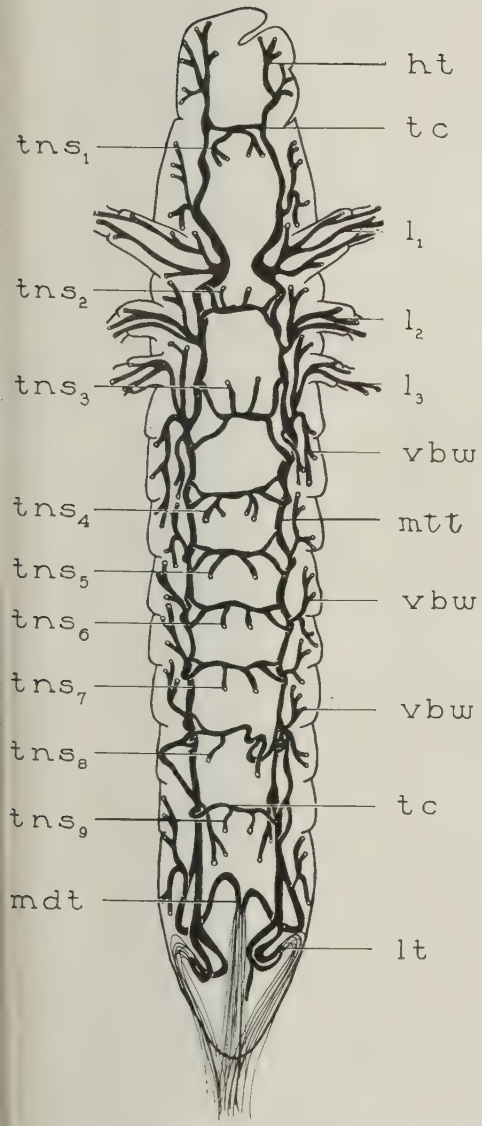

Fig. 1

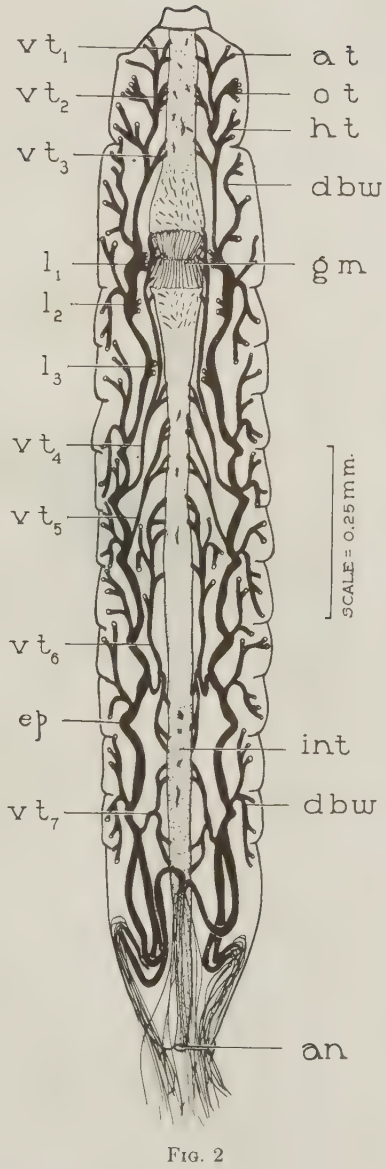

Fig. 2

EXPLANATION OF PLATE LXVIII

FIG. 1. Dorsal aspect of respiratory system of intermediate instar larva. Caudal chamber and filaments not shown

FIG. 2. Ventral aspect of respiratory system of intermediate larva, showing caudal chamber and continuation of main tracheal trunks into caudal filaments

Caudal filaments diagrammatically drawn; their number is greatly reduced in the figure

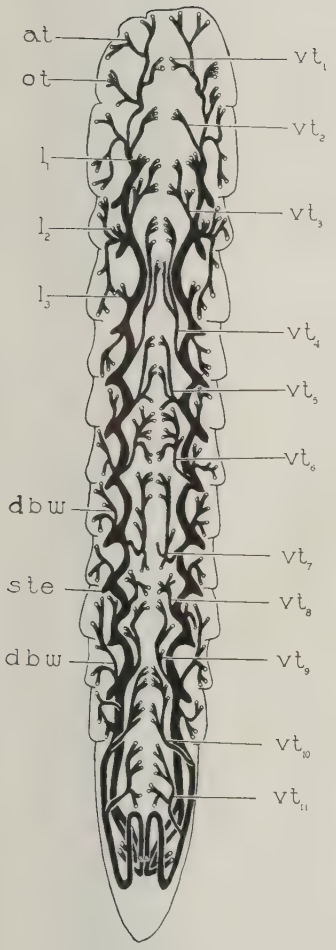
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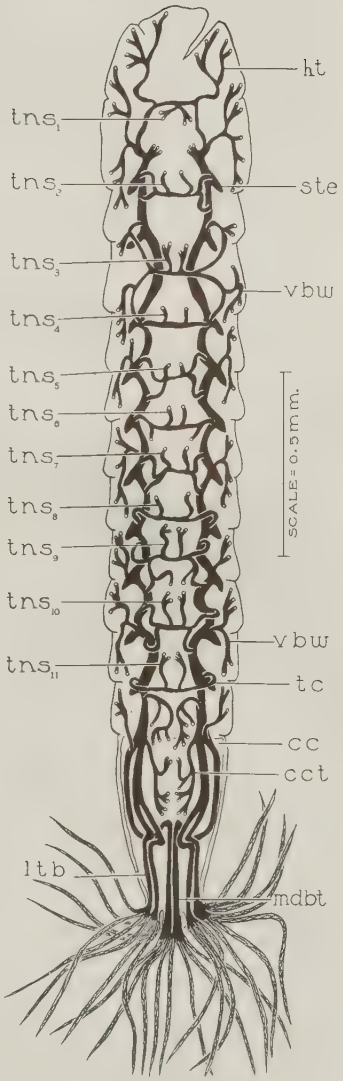
Fig. 1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SCALE = 0.5 m.m.

Fig. 2

EXPLANATION OF PLATE LXIX

FIG. 1. Dorsal aspect of the respiratory system of last instar larva. Caudal chamber and caudal filaments not included in figure

FIG. 2. Ventral aspect of the respiratory system of last instar larva. Caudal chamber and filaments not included in figure

FIG. 3. Sagitto-lateral view of head and thorax of last instar larva, showing portion of one main tracheal trunk and tracheation of legs

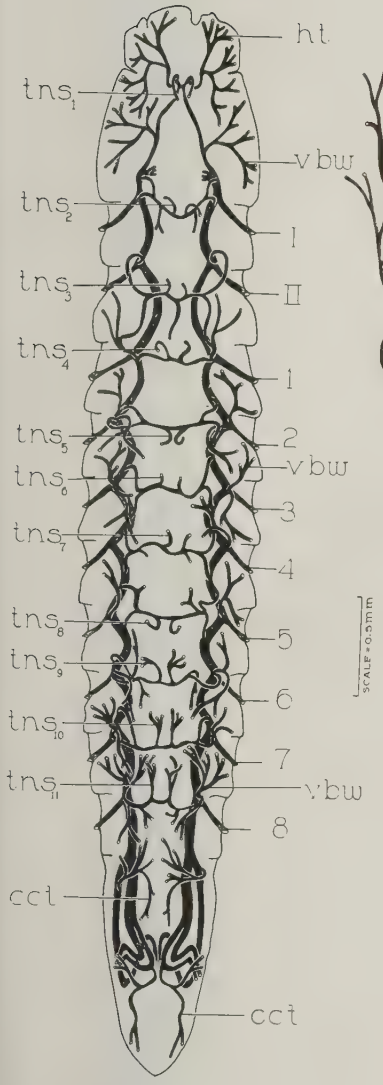


Fig. 1

Fig. 3

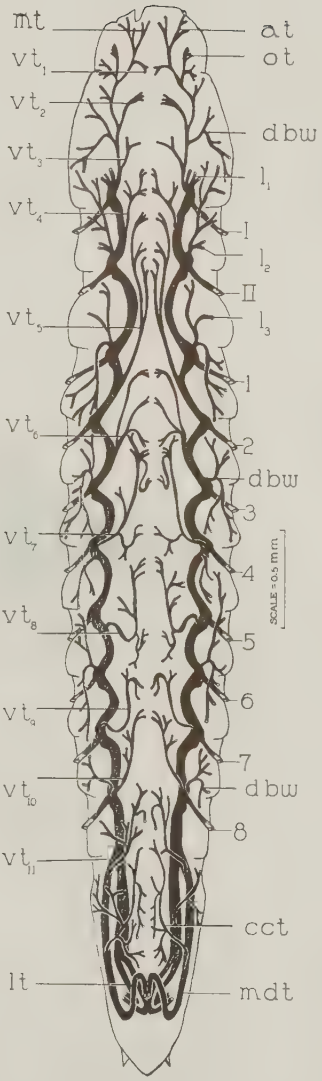


Fig. 2

EXPLANATION OF PLATE LXX

FIG. 1. Diagram of caudal chamber and caudal filaments of last instar larva and their relation to main tracheal trunks. Filaments represented less than one half actual number

FIG. 2. A. Side view of abdominal spiracle, greatly enlarged, showing vestibule and "ear"

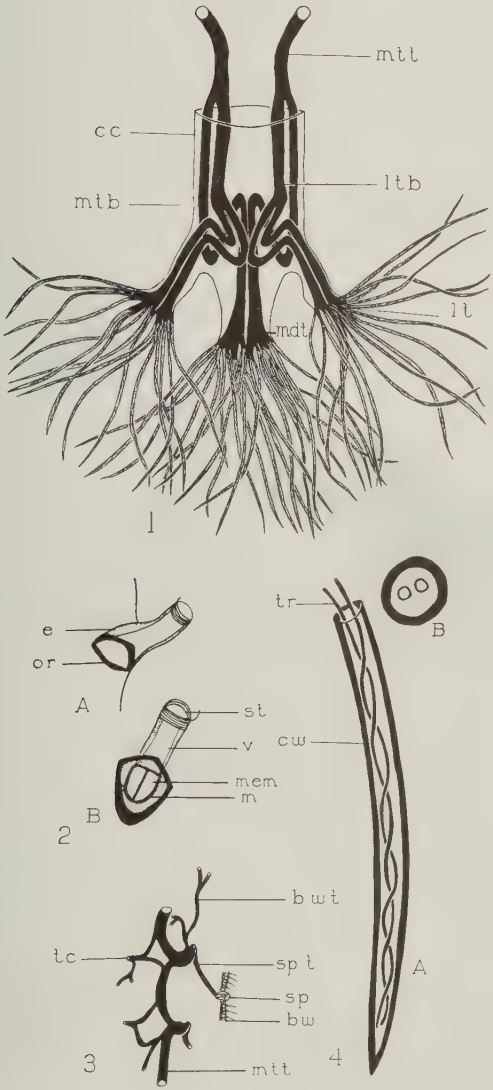
B. Face view of spiracle. Aperture or "mouth" of spiracle closed by two membranes fused in middle and attached along periphery of spiracular aperture

FIG. 3. Abdominal spiracle, showing connection with tracheal system

FIG. 4. A. Longitudinal view of caudal filament, greatly enlarged

B. Transverse view of the same filament

PLATE LXX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THE EGGS AND THE CORACIDIA OF *DIPHYLLOBOTHRIUM LATUM* *

TEUNIS VERGEER

EGGS

Variation in size

MAGATH (1919) reviewed the literature dealing with the eggs of *Diphyllobothrium latum* and described eggs secured by him from a human case. He emphasized the variations in the eggs he studied. From this review of the literature and his own study it is evident that the eggs of *D. latum* range from 50 to 76 μ in length, and from 35 to 56 μ in width. Faust (1929) gives the sizes as ranging from 55 to 80 μ by 41 to 56 μ. Other authors do not report maximum sizes larger than 50 μ in width and 71 μ in length. It is interesting to note that Leuckart (1886) stated that the eggs are about 35 by 50 μ. It is not always clear whether the measurements were made from fresh or preserved material, from eggs of one or of more worms, and whether they were from human or mammalian cases.

To determine the effect of preservation and mounting on the size of the eggs I measured forty fresh eggs taken from the uterus of one tapeworm and found that their average size was 42 by 60 μ. Neighboring segments of this same worm were fixed in an acetic solution of corrosive sublimate, run up through graded alcohols, xylol, and paraffin, then sectioned, mounted, and stained in haematoxylin and eosin. This process caused a shrinkage which reduced the average size to 40 by 58 μ. The eggs in the first part of the uterus, just after leaving the oötype, have thinner shells than those nearer the uterine pore. Forty eggs taken from the posterior part

* Contribution from the Department of Zoölogy, University of Michigan. One of a series of reports on Broad Tapeworm Investigations supported by grants Nos. 96, 131, and 158 of the Committee on Scientific Investigation of the American Medical Association made to Dr. George R. La Rue and the late Dr. A. S. Warthin. This is the second paper on work done as Fellow in Medicine of the National Research Council, 1930–31.

of a uterus averaged 44.5 by 63.2 μ. Eggs from the same segment near the uterine pore averaged 46 by 66 μ. Newly produced eggs are, therefore, about 1.5 μ narrower and 1.8 μ shorter than older eggs in the same uterus. While one is preparing slides of these tapeworms most of the older eggs collapse; hence the investigator is inclined to measure the younger eggs, but in dealing with eggs from feces he uses older ones exclusively. In the measurements of eggs from mounted material one must therefore make an allowance of about 1.5 by 1.8 μ for age plus about 2 μ in both dimensions for shrinkage.

Different specimens of *D. latum* also produce eggs the average measurements of which vary considerably. As indicated in Table I, the smallest average size of eggs is 55 by 39 μ, in host M15; the largest average size is 68 by 48 μ, in host 1152. The smallest eggs of the last lot, however, equal the average size of the first lot; its largest eggs (66 by 44 μ) approach the largest average size.

After forty eggs from a fresh uterus had been measured, they were left in water for twenty-four hours and measured again. When fresh, they averaged 44.1 by 62.2 μ, but twenty-fours later they measured 45.6 by 64 μ, an average increase of 1.5 μ in breadth by 1.8 μ in length. A similar, but smaller, increase was noted when the whole proglottis was left in water. Leaving the eggs in water until hatching causes an additional increase in size of only a few tenths of a micron. This indicates that almost all absorption of water takes place during the first twenty-four hours.

That the same tapeworm may produce eggs whose average size varies from time to time is shown in Table I. Lots 1088 and 1152 are pieces from one tapeworm, as later treatment of the child patient proved. Since she was kept under constant supervision prior to treatment, she could not have lost a tapeworm. Piece No. 1088 was passed about a year before piece No. 1152. Since the latter piece was left in water for three or four days, a reduction of about 1.5 μ should be made from the size of the eggs of No. 1152 to make the measurements comparable with those of No. 1088. After this reduction there remains an average difference of 2.5 by 4.5 μ. It may also be stated that, in general, the eggs first produced by a young segment are smaller and more elongate than later eggs. The average size of eggs produced by *D. latum* grown in dogs is also smaller than when grown in man, as shown in Table I.

TABLE I

VARIATIONS IN SIZE OF EGGS FROM DIFFERENT SPECIMENS OF *D. LATUM*

All measurements are in microns.

Host	Collection No.	Average length	Average width	Range of lengths	Range of widths	No. of eggs used	Remarks
				Fresh material			
Dogs	1210	60	42	37–64	38–46	50	From uterus
	1215	62	44	59–64	42–47	30	From feces
	1224	63	43	61–66	42–46	25	From uterus
	1222	64	45	61–68	42–47	25	From uterus
				Mounted material			
Dogs	M15*	55	39	51–66	34–44	20	
	1098	55	40	51–63	35–43	30	
	M25	56	38	50–61	32–43	30	
	M12	56	38	51–63	30–41	20	
	1085d	56	38	51–59	32–42	30	
	1096	56	41	51–63	38–44	30	
	M24	56	42	44–62	32–46	30	
	1099	57	38	51–63	34–41	30	
	1085b	60	38	57–66	34–44	27	
	1095	60	40	51–68	37–47	30	
	1104	60	42	54–64	39–44	50	
	1124	61	38	47–69	32–44	26	
	12095	61	39	59–66	37–42	20	
	M55	61	44	51–68	42–46	30	
	1068a	63	41	56–67	39–43	20	
Man	1039	60	41	52–68	39–46	30	From immigrant
	1082	62	42	59–68	39–46	30	Tapeworm from Germany
	1084	62	43	55–68	38–47	20	From immigrant
	1088	64	42	51–71	34–45	27	From native
	1152	68	48	61–71	44–54	20	About one year later from same native
Bear	1138	61	42	55–66	39–46	20	From experimental infestation

* M indicates natural infestation in dogs; all tapeworms from man were also natural infestations.

My studies on the eggs of *D. latum* indicate that the sizes of normal fresh eggs vary at least from 48 to 75 μ in length and from 33 to 57 μ in width. In all probability all conflicting reports of authors on the size of the eggs are correct, although the maximum length of 80 μ indicated by Faust (1929) seems to be rather high. That the range in the size of eggs of other tapeworms is at times also very large can be learned from a study of the eggs of *B. cuspidatus*, a tapeworm which reaches maturity in the intestine of the walleyed pike. Cooper (1918) gives their size as 62 to 66 μ by 42 to 45 μ. Essex (1928) reports their size as 49 to 56 μ by 32 to 42 μ. Incidentally, with the development of the procercoids of *B. cuspidatus*, I studied the eggs of this worm and found that the fresh eggs extruded in water averaged only 32 by 46 μ. The relation of length to width, however, is the same as that of the eggs measured by Cooper.

FORM AND STRUCTURE

In shape the eggs of various worms also differ somewhat. The lowest ratio between the average width and length is 1 : 1.33; the highest is 1 : 1.61. In general, the eggs are widest very near the middle, but toward the end with the nodule. Considerable variation is noticeable between one egg and another in the degree of tapering toward the cap end. At times they are almost perfect ovals, but at other times they are rather pointed toward the cap, and all intergradations between these two forms may be found. The end with the nodule is almost uniformly rounded. The eggs of *D. latum* are never so pointed as those of *D. mansoni* and other Far Eastern Pseudophyllideans. Magath (1919) stated that a definite diagnosis cannot be made from the measurements of the eggs, but that "the cap on one pole and the small thickened nodule at the other clinch the diagnosis." It is true that this nodule has often escaped the observation of workers, and that it is characteristic (although not always present) for the eggs of *D. latum*. It is also true, as Magath justly observes, that this structure, as well as the cap at the other end, becomes more conspicuous as the eggs mature. Moreover, it is often very difficult, if not impossible, to observe these characters in prepared slides, and especially so in whole mounts of proglottides. Neither of these characters, however, is specific for *D. latum*. I have observed both structures on the eggs of *D. mansoni* and they

possibly hold for all tapeworms of the subgenus *Spirometra* Faust, Campbell, and Kellogg (1929). The same structures are noted by Talysin (1930) for *D. minor* Chol., the eggs of which are almost identical with those of *D. latum*. Doubtless these characters have often escaped observation. They may hold for the whole genus *Diphyllobothrium*. I have observed these structures in the genus *Bothriocephalus*, and they are common on trematode eggs; note in particular *Paragonimus* and *Polystoma*.

In the hosts of the broad tapeworm many other species of the genus *Diphyllobothrium* may occur; the sizes of their eggs overlap *inter se* and with those of *D. latum* (Meggitt, 1924). There is thus no combination of characters sufficient for the positive identification of the eggs of *D. latum;* hence only a provisional identification can be made in endemic regions where other parasites with similar eggs have not been reported.

The cap of the egg of *D. latum* is rather large as compared with caps of some other pseudophyllidean eggs. Its diameter measures about 20 μ. Although not observed in fresh eggs, another character becomes evident in older eggs, especially when the cap is pressed open or the egg hatches. It is then seen clearly that the union between the egg and the cap does not make a straight line, but is distinctly and rather irregularly sutured, as shown on Plate LXXI, Figure 1. However, this suturing has also been observed by Zeller (1872) in the eggs of *Polystoma integerrimum*, and may be found to be common. The ovum within the yolk measures 13–15 μ, and the yolk cells measure about 10 μ each. The cells break down in older eggs.

EMBRYOLOGY

According to Vogel (1929), the intensive work of Schauinsland (1886) on the development of the eggs of Bothriocephalidae and *D. latum* was so accurate that only in very minor details may improvement be possible. Schauinsland's findings, which I can confirm in the main for eggs of *D. latum*, may be summarized as follows: Within the egg a single ovum can be observed surrounded by several yolk cells, which are easily distinguished in young eggs but which break down in older eggs. The ovum soon divides by mitosis, and one of the blastomeres escapes to the surface of the yolk, where it divides once or twice more, resulting in a very thin vitelline mem-

brane just within the eggshell. The nuclei of these cells are thicker than the membrane is, and they may thus be seen projecting into the yolk, as illustrated in Plate LXXI, Figure 1.

The remaining blastomere also divides twice, resulting in four cells, one of which divides later in such a manner that the cells which develop from it spread around the three others, which in the meantime also divide repeatedly (Pl. LXXI, Figs. 1–2). The latter group of cells represents the endoderm; the former, the surrounding ectoderm. Round about this embryo is the yolk material. The cells of the ectoderm continue to divide, and gradually, because of growth and increase in their number, the membrane becomes thicker while on its outer surface cilia develop, which first are short but become longer (Pl. LXXI, Fig. 3). This, then, is the ciliated outer membrane or embryophore. The inner cell mass becomes the onchosphere. As the embryo grows, the yolk decreases, but not all of it is ever used up. When the egg hatches, a few of the yolk cells are sometimes still intact, although the nuclei have generally broken down. Occasionally one can also see part of the vitelline membrane remaining within the empty shell (Pl. LXXI, Fig. 4). If we accept Schauinsland's interpretation, then the onchosphere and the forms which develop from it consist of endoderm and mesoderm only; the outside of the onchosphere and, consequently, of the adult worm is endoderm, and through it food from the contents of the intestine of the host is absorbed. The reproductive organs and other inner tissues must be mesodermal derivatives.

FACTORS INFLUENCING DEVELOPMENT

The time required for the development of eggs of *D. latum* appears to depend on several factors. I succeeded in hatching eggs in an incubator at 28° C. (82.4° F.) in six days. Vogel (1929) hatched eggs in a week at 26° 28° C. In summer at room temperature they hatch in ten to twelve days, and in winter in a room heated to about 70° F. they hatch in twelve to fourteen days. Schauinsland (1886) and Leuckart (1886) found that several months were required and that the hatched coracidia lived about a week. From my studies of the coracidia (see below) it may be inferred that the temperature of the water must have been at about 50° F. Schauinsland (1886) stated also that in an incubator (temperature not recorded) they hatched in twelve to fourteen days.

Cold temperatures as maintained by modern electric refrigerators almost completely arrest development. Dr. George R. La Rue informs me that eggs left with him on July 31, 1931, were kept under refrigeration until November of 1933, when upon raising the temperature part of them hatched. In November of 1934 still others were allowed to hatch, and some still (March, 1935) continue under refrigeration. Evidently at sufficiently cold temperatures above freezing the eggs do not hatch, but remain viable for at least three and one-half years, probably longer. All these observations indicate that between minimum and optimum temperatures the time required for hatching is inversely proportional to the temperature of the water.

That pressure has a slightly retarding influence, especially on the hatching, has been claimed by Vogel (1929). After the eggs had been transferred from the bottom of a cylinder 5 cm. in diameter, which contained a column of water 15 cm. high, to a very shallow dish, they hatched in large numbers even in the dark. Vogel believes that the pressure of the column of water prevented the hatching. It appears to me that during development the oxygen supply in the bottom of the cylinder was greatly reduced and that the subsequent aëration or change of water provided the necessary oxygen, which then served as a stimulus to hatching. He also finds that eggs develop equally well in the dark and in the light, but that eggs in the dark do not hatch until brought into the light.

I found that in hatching it is immaterial whether eggs are just produced or older. Eggs were taken from the uterus of a well-developed tapeworm, only sixteen days old, which was 108 cm. long, with a maximum width of 12.5 mm., and also from a ripe segment of a much older, well-developed tapeworm. More than 90 per cent of each lot hatched within fourteen days. Not all tapeworms develop equally well, and not all the eggs of undersized poorly developed tapeworms hatch well. Eggs were taken from one such tapeworm which was 35 days old and measured 25 cm. long and 6 mm. wide. They were treated in exactly the same manner as the first two lots. All lots were kept together and at the same temperature, but after 14 days only 2 per cent had hatched, whereas after 37 days 15 per cent had hatched. At that time immature coracidia arrested in their development were observed in an additional 14 per cent of the eggs, and the remaining 71 per cent did not begin development.

R. A. Wardle (1935) believes that some eggs fail to hatch because they are not fertilized, and that this lack of fertilization is most common in undersized tapeworms from smaller animal hosts. I have found that the food of the host is also an important factor in the development of *D. latum* worms and that by regulation of the diet much larger worms can be grown in dogs. The diet of the host may be one factor in explaining the extremely low hatching percentage of eggs obtained from dog feces by Essex and Magath (1931).

These authors also report in the same paper that freezing as well as drying kills the eggs.

CORACIDIA

Within the normal egg of *D. latum* the coracidium is visible about two to four days prior to hatching. Two days before hatching movement becomes noticeable, first in the hooks and later occasionally in the body of the onchosphere. Within the egg the coracidia of *D. latum* measure 35 to 45 μ. They originate near the nonoperculated end of the egg, and before hatching move to the operculated end. The hooks always move out in pairs, only one or two pairs at a time; toward the end of a single movement the paired hooks separate a little farther. In addition to the coracidium cells of the vitelline membrane and some leftover yolk granules are visible within the eggshells. The egg of *D. latum*, with a mature coracidium inside, is shown in Plate LXXI, Figure 5. For a hatched coracidium see Plate LXXI, Figure 6.

I have not observed natural hatching. It is described for *D. latum* by Vogel (1929), who succeeded in taking moving pictures of it. He states that suddenly the cap burst open without effort on the part of the coracidium, which then was forced into the opening by pressure from within the egg, when its own movement caused the ultimate emergence. Mature coracidia can be forced to hatch by applying gentle pressure on the cover glass of a mount of eggs. Since the caps are much narrower than the coracidia, the latter must become as narrow as the cap. When part of the coracidium protrudes, the coracidium momentarily becomes hourglass-shaped and then is liberated. The cap on the eggs of *D. latum* is about 20 μ in diameter. After hatching it remains attached at one side of the egg and opens up wide.

There seems to be a definite correlation between the time required for the hatching of the eggs and the length of life of the coracidia, both being conditioned by the temperature of the water. Above 70° F. the coracidia of *D. latum* live no longer than 48 hours, but when separated from eggs and placed in a refrigerator at 48° to 52° F., they live seven to nine days. The longer the life of the coracidia the greater the likelihood of their being eaten by copepods; northern copepods are probably as abundant during the summer in northern waters as southern forms in southern waters. If this statement is true, the possibility of completing their life cycle is greater for coracidia in the cooler waters of the north than in the warmer waters of the south. The greater longevity of the coracidia in cold water may be one reason why *D. latum* is primarily northern in its distribution.

The coracidia and the procercoids have been fully described by Vogel (1930).

FIRST INTERMEDIATE HOSTS OF *D. LATUM*

The first intermediate hosts of the procercoids of *D. latum* include the following in Europe: *Cyclops strenuus, Diaptomus gracilis, D. castor, D. vulgaris,* and *D. graciloides;* Essex (1927) found that in North America *D. oregonensis* serves as host; Magath and Essex, in a paper read in December, 1930, before a joint meeting of the Society of Tropical Medicine and the American Society of Parasitologists, reported that *D. sicilis* and *D. siciloides* also serve as hosts in the waters of Manitoba.

Infestation experiments with hundreds of thousands of coracidia of *D. latum* were performed with 138 specimens of *Cyclops bicuspidatus,* 45 of *C. americanus,* 14 of *C. brevispinosus,* 12 of *C. fimbriatus,* 11 of *C. prasinus,* 11 of *C. serrulatus,* 10 of *C. albidus,* 9 of *C. leuckarti,* 3 of *C. ater,* 1 of *C. phaleratus,* 31 of *Diaptomus minutus,* and hundreds of other unidentified specimens of *Cyclops* and *Diaptomus.* The copepods readily swallowed the coracidia. In the stomach of one *D. minutus* fourteen coracidia of *D. latum* were observed at one time, but they failed to penetrate. Thirty other specimens of *D. minutus* also failed to become infested, although they ate the coracidia freely. In only two of these copepods did one *D. latum* onchosphere penetrate into the body cavity. The following day the procercoids were almost motionless, and the third day a light cyst

which had formed from the stomach wall enclosed and attached the motionless procercoids to the stomach. They never developed and were soon reduced to unrecognizable masses of tissue, which gradually became smaller.

Essex (1927) experienced a similar failure in the development of the procercoids of *D. latum* in *C. prasinus* and *C. brevispinosus.* In the body cavities of these species a very small percentage of procercoids happened to penetrate, but after seven days they had undergone little development. Vogel (1930) found that *C. strenuus* is not dependable as a host of *D. latum* procercoids, since one strain may be susceptible and another not; one strain failed to become infested although he exposed more than four hundred of them to feeding experiments. Evidently only certain species of *Diaptomus* are well adapted to serve as hosts of *D. latum*, whereas the species of *Cyclops* can be regarded only as accidental or abnormal hosts.

SUMMARY

The average sizes of the eggs of *D. latum* vary according to the state of preservation. They vary in different parts of the same uterus (an age difference), in different segments of the same worm, and with the age of the worm. Corresponding segments of different worms of corresponding ages produce eggs of different average sizes. The average size of the eggs is also partly dependent on the host. No features of the egg present characters for the identification of the species.

The embryology of the egg indicates that the outer surface of the adult worm is endodermal; the ectodermal ciliated outer membrane is shed.

A far greater percentage of the eggs of well-developed tapeworms hatch than of undersized poorly developed worms.

Between minimum and optimum temperatures the time required for hatching is inversely proportional to the temperature of the water. At 28° C. eggs hatch in six days. Near freezing they remain viable for at least three and one-half years without hatching. The oxygen supply is probably also important. The age of the egg does not influence the rate of development.

The length of life of the coracidium is inversely proportional to the temperature of the water. It lives from about two days at 70° F. to nine days at 48°–52° F. Its greater length of life in colder waters

is probably one reason why the broad tapeworm is common only in temperate and northern regions.

The North American hosts of the procercoid, as determined by others, are *Diaptomus oregonensis*, *D. sicilis*, and *D. siciloides*, cold-water forms of northern distribution. The following species of Copepoda cannot serve as hosts: *Cyclops bicuspidatus*, *C. americanus*, *C. brevispinosus*, *C. fimbriatus*, *C. prasinus*, *C. serrulatus*, *C. albidus*, *C. leuckarti*, *C. ater*, *C. phaleratus*, and *Diaptomus minutus*.

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BIBLIOGRAPHY

Cooper, Arthur Reuben. 1918. North American Pseudophyllidean Cestodes from Fishes. Illinois Biol. Mon. 4: 288–542, 13 pls.

Essex, H. E. 1927. Early Development of *Diphyllobothrium latum* in Northern Minnesota. Journ. Parasitol., 14: 106–109.

—— 1928. On the Life History of *Bothriocephalus cuspidatus* Cooper, 1917. A Tapeworm of the Wall-eyed Pike. Trans. Am. Microsc. Soc., 47: 348–353.

—— and Magath, T. B. 1931. A Comparison of the Viability of Ova of the Broad Fish Tapeworm, *Diphyllobothrium latum*, from Man and Dogs: Its Bearing on the Spread of Infestation with This Parasite. Am. Journ. Hyg., 14: 698–704.

Faust, E. C. 1929. Human Helminthology, xxii + 616 pp. Philadelphia.

—— Campbell, H. E., and Kellogg, C. R. 1929. Morphological and Biological Studies on Species of *Diphyllobothrium* in China. Am. Journ. Hyg., 9: 500–583.

Leuckart, K. G. F. R. 1886. Die Parasiten des Menschen und die von ihnen herruhrenden Krankheiten, 2. Aufl., V. 1, 1. Abt., xxi + 855–1000 pp., 57 figs. Leipzig and Heidelberg.

Magath, T. B. 1919. The Eggs of *Diphyllobothrium latum*. Journ. Am. Med. Assn., 73: 85–87.

Meggitt, F. J. 1924. The Cestodes of Mammals, 282 pages. M. Neveu-Lemaire and J. Pelligrin, London.

Schauinsland, H. 1886. Die embryonale Entwicklung der Bothriocephalen Jenaische Zeitschrift für Naturwissenschaft, 19: 520–573, pls. 7–9.

Talysin, Th. 1930. *Dibothriocephalus minor* Chol., Der kleine Bandwurm Transbaikaliens. Zeitschrift für Wiss. Biol., Abt. F, Zeitschrift für Parasitenkunde, 2: 535–550, 17 figs.

Vogel, H. 1929. Studien zur Entwicklung von *Diphyllobothrium*. I. Teil: Die Wimperlarve von *Diphyllobothrium latum*. Zeitschrift für Wiss. Biol. Abt. F, Zeitschrift für Parasitenkunde, 2: 213–223, 6 figs.

—— 1930. Studien über die Entwicklung von *Diphyllobothrium*. II. Teil: Die Entwicklung des Procercoids von *Diphyllobothrium latum*. *Ibid.*, 2: 629–654.

Wardle, R. A. 1935. Fish-Tapeworm. Biological Board of Canada. Bull. 45: 1–25, 6 figs.

Zeller, E. 1872. Untersuchungen über die Entwicklung und den Bau des *Polystomum integerrimum* Rud. Zeitschrift für Wiss. Zool., 22: 1–28, 2 pls.

EXPLANATION OF PLATE LXXI

Diphyllobothrium latum

Abbreviations: EC, ectodermal cell; EN, entodermal cell; VM, vitelline membrane; YC, yolk cell.

The lines near the figures represent 0.02 mm.

Figs. 1–2. Segmented eggs, showing origin of ectoderm and endoderm. Tissues shrunk away from the egg shell owing to fixation. Modified after Schauinsland

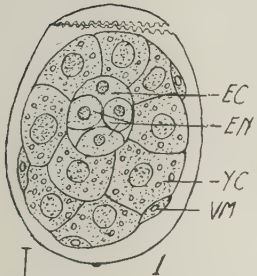
Fig. 3. Immature embryo, showing development of cilia. After Schauinsland

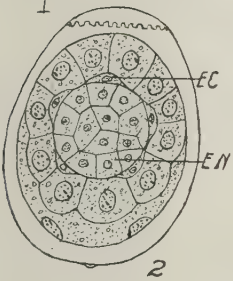
Fig. 4. Egg just after liberation of the coracidium

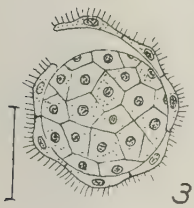
Fig. 5. Egg a few hours before hatching

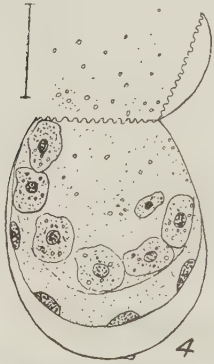
Fig. 6. Vogel's figure of the coracidium by dark field illumination

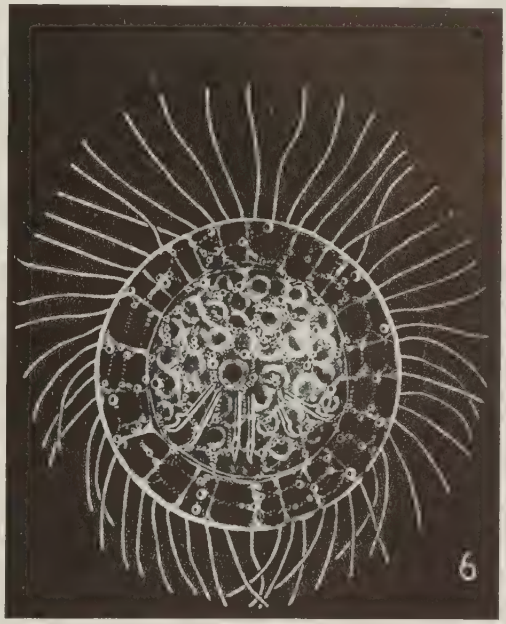
PLATE LXXI











LIMNOLOGICAL INVESTIGATION OF A STRONGLY BASIC BOG LAKE SURROUNDED BY AN EXTENSIVE ACID-FORMING BOG MAT *

PAUL S. WELCH

IN THE past bogs have received attention from plant ecologists, and many of their unique vegetation features are now well understood, but there has been no definite effort in America to work out the limnology of those bodies of open water, sometimes of conspicuous size, which often occupy the central area of the larger bogs or which possess bog margins to such an extent that the physical and chemical features of the water may be profoundly influenced. The University of Michigan Biological Station is surrounded by many unusually diversified bog lakes. No fewer than two dozen are situated within a radius of a few miles. They present conditions which vary from the most acid through intergrades to by far the most alkaline water of that whole region. Since this situation offers such an inviting opportunity, the limnological program of the writer has included, for many years, investigations of these unique waters.

This paper is the first of a series on the general limnological features of these bog lakes; others will appear in the near future. Certain of these papers will deal with individual lakes, each of which represents a distinct type of bog lake. Unfortunately, bog lakes are as yet so little known from the limnological standpoint that a satisfactory classification of them is still lacking. Davis (1907), Dachnowski-Stokes (1933), Auer (1933), and others have proposed classifications of American peat bogs and peat deposits, but these are pioneering efforts, and the limnologist finds difficulty in making them meet his needs for a bog *lake* classification. Therefore, in the absence of an established set of specific and understandable names for the different types of bog lakes, in this series of papers it will be necessary

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to designate the different types studied by a characterizing title and to depend upon detailed description of the lake and its immediate surroundings for the proper recognition of such a type.

The writer chooses to define a bog lake as follows: an area of open water, commonly surrounded, either wholly or in large part, by true bog margins; possessing peat deposits either about the margins or in the bottom, or both; usually with a false bottom composed mostly of very finely divided, flocculent vegetable matter; containing considerable amounts of colloidal materials; and usually so constituted genetically that at some future time it may become completely occupied by the higher vegetations so characteristic of those bogs which have lost all open water previously possessed.

Owing to differences in degree of development or to certain special circumstances, bog lakes do not always possess all these characteristics at all times during their history. For example, a bog lake may have once possessed a narrow, marginal floating mat and accompanying marginal peat deposits, but failure of the marginal mat to keep pace with rapidly falling water level may lead to the complete and permanent separation of water and mat, and result in the subsequent disappearance of the latter. Bog lakes are also known in which no marginal mat has been formed and in which the peat deposits have originated primarily from the remains of the submerged, rooted aquatic vegetation within the lake itself. Other forms of deviation from the typical condition described above may be found, but in every instance peat is present.

One result of these investigations has been the discovery of an unexpected diversity of physicochemical features in different bog waters. It should be noted that the water referred to in this paper is, unless otherwise specified, the open water of the bog lake proper, and not that water contained in the marginal mats. This paper describes a bog lake, typical in every respect, which contains the most alkaline water of the whole general region, although the marginal conditions are such that an altogether different set of physicochemical features would be expected.

ACKNOWLEDGMENTS

The writer is indebted to Dr. J. K. Gwynn Silvey, Dr. David C. Chandler, Dr. Donald E. Miller, and Mr. Carl E. Hoffman, who served as research assistants at various times during the course of

this work; to Dr. W. C. Gorham for the use of certain unpublished data which appear in this paper; to Professor George E. Nichols for assistance in the identification of certain phytoplankters and for other assistance in matters relating to the Algae of the Douglas Lake region; and to Dr. Alma B. Ackley for unpublished information relating to the Algae of Michigan.

METHODS

All temperature records were made with Negretti and Zambra reversing thermometers. Water samples for the various physical and chemical analyses were secured with a modified Kemmerer water bottle. Color was measured with a standard United States Geological Survey set of glass disks. Most of the chemical analyses followed the methods outlined in *Standard Methods for the Examination of Water and Sewage* (sixth and seventh editions, 1925 and 1933). Hydrogen-ion concentration was determined by the use of three different methods: (*a*) colorimeters prepared by the LaMotte Chemical Products Company, Baltimore, Maryland; (*b*) Hellige Standard Color Discs Colorimeter; and (*c*) an electrometric apparatus. Since bog waters differ in color and chemical content from other kinds of lake waters, samples were often tested by more than one method in order to insure the dependability of results. Conductivity was measured by means of an Evershed and Vignoles Dionic Water Tester. Plankton samples, for both qualitative and quantitative purposes, were secured by well-known, standard plankton net (No. 20) methods. Plankton samples were also secured by the use of a Foerst electric centrifuge.

Owing to the peculiar nature of the floating mat margins of many bog lakes and to the ease with which the flocculent materials of the false bottom come up into flotation and interfere with tests and samples, ordinary rowboats and canoes are not adapted to work of this sort. A small duckboat of the usual pattern was helpful, but the most satisfactory craft was found to be a pneumatic boat which combined the advantages of light weight, ease of handling, stability, very small depth displacement, and a minimum of surface water disturbance when in use.

DESCRIPTION

The lake on which this work was done is known as Mud Lake. It is located in Sections 7 and 8 (largely in the latter) of Inverness

Township, Cheboygan County, Michigan. An excellent account of this lake and its surroundings, particularly the latter, from the general standpoint of plant ecology has been published by Goe, Erickson, and Woollett (1925). Jewell and Brown (1929) likewise described many features of this lake, both botanical and zoölogical, and made a survey of the larger animals occurring both in the lake proper and in the water held by the extensive bog mat. They also made certain physical and chemical analyses of the water. These accounts, notably that of Goe, Erickson, and Woollett, make unnecessary here any description of the botanical features of the immediate surroundings of this lake. Their detailed map, especially of the sphagnum mat and other botanical features, furnishes an excellent picture of the general biological conditions. Jewell and Brown also present a map which gives additional information, particularly with respect to certain chemical features. These maps tell the story in a much more adequate and understandable form than any description would. From them it will be evident to the reader that this lake is surrounded by a floating marginal mat; that this mat is narrow in some portions of the periphery, very extensive in others; that most of the marginal mat is either of a typical Chamaedaphne-Sphagnum type or of the Carex type; and that the copious supply of water impounded in the mat is acid in reaction, having an acidity as high as pH 3.2 in the Chamaedaphne-Sphagnum sections. The lake is, then, a *unique situation in which the open water (the lake itself) maintains a high alkalinity, although margined completely by a bog mat supersaturated with water which is acid in reaction.* Herein lies the unusualness of the situation. From all external signs an observer would expect this bog lake to have the same acid character as do the innumerable other northern so-called sphagnum bog lakes. It is the only bog lake of this type which the writer has ever seen. Doubtless others do occur, but apparently are rare. There are other bog lakes in the Douglas Lake region which are alkaline in reaction, although not attaining the degree of alkalinity of Mud Lake, but they are all bog lakes of a different type, with different surroundings and margins. So deceiving is the vegetation picture at Mud Lake that it is possible that only by a series of chemical tests would another situation of this kind be discovered.

MORPHOMETRIC FEATURES

The following data are taken from a plane-table map made in 1922 by Professor Frank C. Gates, the writer, and helpers. This lake has been under constant observation since that time, and the marginal changes have been so slight that another map is unnecessary.

Mud Lake has a shore line of about 1,350 meters (4,450 feet) and an area of about 104,190 square meters (1,121,000 square feet). Its maximum length is about 585 meters (1,920 feet); its maximum breadth about 256 meters (840 feet); and its mean breadth, 178 meters (583 feet). Its main axis has a northwest–southeast direction. Determinations of volume are impracticable because of the nature and the position of the false bottom.

A small inlet enters the southeast end of the lake and a small outlet leaves the far northwest end. At no time during the summer season is a current detectable in the inlet, and the outlet seems to function only during the spring, when the water level is high, or during the summer after an unusually heavy rain. It is evidently to be classed as a seepage lake.

One of the conspicuous features of this lake is its extensive false bottom, the top of which now lies near the water surface. The amount of free, open water above the top of the false bottom depends upon the season and the amount of rainfall. In 1921 falling water level resulted in a large area of the false bottom reaching the surface at the southeastern end late in the summer. During the two succeeding summers it was completely submerged. At that time the free, clear water above the false bottom varied in depth from 5 to 8 centimeters in some places to not more than 1 meter in others. Since that time there have been variations in the different years, but on the average there has been a slow yet definite rising of the false bottom to the surface at the southeastern end of the lake until now (1934) it seems to be permanently established above the water level and, in fact, certain plants with apparently minimal anchorage requirements have invaded this field of tenuous mud and are rapidly capturing it. Changing water level alters the position of emergence of the mud from the free water, so that the exposed area is greater late in the summer. Lakeward from this exposed mud area the free, open water grades off very gradually to a depth of 0.6–1.0 meter (early in the season) near the north and the west shores. This

area of deeper water is not extensive, so that often a large part of the lake area has open, clear water only to a depth of 10–30 centimeters. On October 13, 1933, the writer found no free water with a depth greater than 10-20 centimeters, but on May 4, 1934, the water level was again high enough to provide clear water at the northwest portion to a depth of 0.6–1.0 meter, and at the southeast end the false bottom was again covered with water except in a few places. Jewell and Brown (1929) observed a depth fluctuation of the clear water above the false bottom from day to day. The false bottom appeared nearer the surface after strong winds and on bright, sunny days, but after a few calm, cloudy days it settled to a somewhat lower level.

This false bottom is composed of very finely divided, flocculent vegetable matter which, under summer conditions, comes up into flotation in the superimposed water with the slightest disturbance. In late autumn, when temperatures of both free water and false bottom are much lower, the surface layer of the false bottom seems to be more compact and is not so easily brought into suspension. The surface layer of the false bottom has a grayish earthy color, and lacks the well-known brown color which is so characteristic of the false bottom materials of "sphagnum" bog lakes. Somewhat deeper brownish materials occur. Not infrequently the top of the false bottom is greenish, owing to generous growths of Algae. This false bottom gradually stiffens with increasing depth until a gelatinous peat is formed.

In 1922 Jewell and Brown made borings in this lake and found that the false-bottom materials and the deeper, gelatinous peat extended to a depth of 2.4–2.7 meters; that below this peat deposit and overlying the sand of the original lake bottom is a layer of marl varying from several centimeters to 1.8 meters in depth, depending upon the location; and that the greatest depth from the lake surface to the bottom of the original lake basin was 6.7 meters and the shallowest was about 2.4 meters. During the following summer Goe, Erickson, and Woollett (1925) made a more extensive series of borings with similar results.

PHYSICAL FEATURES

Wave Action

In spite of the fact that this lake is 585 meters long and that its long axis parallels the direction of the prevailing winds in this

region, wave action is minimal and commonly absent during ordinary summer weather. This condition is due to a combination of several circumstances. The lake is surrounded on all sides, except on the southeast, by high forested hills. A certain forest protection occurs also on the southeast side. In addition, vertical temperature records have shown that the temperature gradient is commonly a steep one and that the thermal resistance in the shallow, underlying water is effective in lessening wind-produced water motion. The gradually increasing density of the false bottom, even though the upper part is very tenuous, constitutes a drag against water movement. Wave action is thus confined mostly to a thin surface layer. Under the action of the stronger, prevailing northwest winds there is a general drift of surface water toward the southeast end of the lake and this, no doubt, accounts for the emergence of the false bottom above the water surface in that region. Under such general surface flowage a certain amount of the lighter flocculent materials of the upper surface of the false bottom is gently but gradually drifted to that end of the lake, and in the absence of effective surface disturbance from the opposite direction these substances accumulate there.

Color

Except when flocculent false-bottom materials are disturbed, the water is quite transparent and the inherent color low. Though never highly colored, it varies in color from time to time. Gorham (unpublished) found that on August 8, 1929, and on August 16, 1930, the color was 76 on the platinum-cobalt scale. Subsequent records made by the writer or his research assistants are as follows: Aug. 14, 1931, 28; Aug. 18, 1933, 24; Oct. 13, 1933, 45; July 23, 1934, 102; Aug. 17, 1934, 61. No explanation of these fluctuations will be attempted here. It should be mentioned that this water never seems to develop the dilute tea or dilute coffee colors which are so characteristic of many of the northern bog lakes.

Thermal Conditions

Owing to shallow depth and position of the underlying false bottom, the water responds more readily to changes in atmospheric temperatures. A warm day often causes the water temperature to rise 6 or more degrees C. above that of the surface water of adjacent

larger lakes. Likewise, a cold night in August has been known to cause a drop of 6 or more degrees in temperature below that of the same adjacent larger lakes, such as Douglas Lake. Nevertheless, the extremes of variation are not so great as might be expected. None of the available records show a summer temperature above 28 degrees. The strikingly variable daily temperatures reported from certain European "moors" have not been found in this lake.

As might be expected, ice forms on this lake much earlier than on the larger ones of the same region. The writer has witnessed a temporary thin ice sheet over the entire lake as early as October 13. The inaccessibilty of the lake has thus far prohibited midwinter examinations. It is certain, however, from what is known about the winter conditions on the neighboring larger lakes that the entire body of water above the false bottom is frozen solid for many weeks. In fact, it seems inevitable that some of the water-saturated upper layer of the false bottom must likewise freeze. It would seem that organisms which inhabit the open water must then be forced deeper into the false-bottom materials to escape ice capture. Whether any of them can withstand long freezing in the ice is not known, but it seems very unlikely that more than a slight fraction, at most, of the biota could survive such an experience.

Turbidity

Since this lake maintains a condition of calm most of the time, the water above the false bottom is very clear and turbidity is low. Turbidity, arising from plankton, is low, since quantitatively the plankton is restricted. A slight turbidity is due to a small amount of very finely divided peaty materials which are essentially nonsettling. Owing to the extreme ease with which materials from the false bottom rise into suspension in the superimposed, open water, a potential high turbidity is present, and actual high turbidity occurs temporarily when winds become sufficiently violent.

Since both color and turbidity are low, it follows that the shallow, open water is illuminated throughout with intensities which are reduced but little from that at the surface. Therefore, organisms occupying this water are exposed to almost a maximum of light. Those which require protection from such intensities have an opportunity to retreat into the suspended upper layer of the false bottom.

CHEMICAL FEATURES

Dissolved Oxygen

It seems to be commonly thought that bog-lake waters maintain little dissolved oxygen. This may be an inference carried over from oxygen determinations made on that water which saturates the floating mat, since there the water is either very low in dissolved oxygen or actually devoid of it. Oxygen content of bog-lake waters varies with the lake and with circumstances, and no generalization can be made. Table I gives results of some of the analyses of Mud Lake water. Nothing can be stated concerning the oxygen content of that underlying water which saturates the false bottom, since there is no satisfactory method for making an analysis in the presence of such quantities of flocculent sediments. It seems probable that the dissolved oxygen content is much reduced there.

It will be noted from Table I that Mud Lake surface water varied from 3.1 p.p.m. on certain dates to as high as 12.5 p.p.m. on others. The unusually high records are from Gorham's work, and his explanation was that bright sunlight, dead calm weather, and a large crop of Algae on the top of the false bottom made it possible for oxygen evolved through photosynthesis to accumulate. Vertical samples showed that ordinarily there is no significant oxygen decline in the clear water above the false bottom.

Free Carbon Dioxide

As will be seen in Table I, the free carbon dioxide was always very limited in amounts or else so small as to be undetectable by the chemical method employed. This result is smaller than might be expected since during the summer, at least, large quantities of decomposition gases are constantly given off from the false bottom, some part of which is probably carbon dioxide.

Alkalinity

In accordance with standard practice, two initial indicators were employed, namely, phenolphthalein and methyl orange.

Phenolphthalein. — Samples from this lake gave such slight reaction to phenolphthalein that the test might almost have been omitted. Sometimes no reaction was recognizable. Titration quantities never exceeded 0.2 c.c. and usually were less.

TABLE I

CERTAIN ANALYSES OF MUD LAKE WATER

All samples are taken from 0 to about 40 cm. depth. Data for 1929 and 1930 are mostly from unpublished records of Dr. W. C. Gorham.

Date	Temp. C.	pH	O_2 in p.p.m.	Methyl orange alkalinity in p.p.m.	Free CO_2 in p.p.m.	Conductivity in reciprocal megohms
1921						
Aug. 21	....	9.0	....	...	...	...
1922						
July 13	19.6	7.4	4.6	...	...	...
Aug. 11	21.2	8.8	5.1	...	...	...
1923						
July 11	19.8	9.0	4.9	...	...	...
1928						
June 29	....	6.8	...	...	...	...
Aug. 7	....	7.8	....	...	...	...
1929						
June 25	15.9	7.7	5.9	117	1.9	...
July 3	17.8	7.4	5.1	120	2.0	...
July 23	26.2	7.8	4.6	121	2.0	...
Aug. 2	21.6	8.7	4.6	121	2.0	...
Aug. 9	23.3	9.0	4.0	132	2.0	...
Oct. 12	11.8	8.6	6.4	134	3.0	...
Oct. 16	11.9	8.2	6.5	135	3.0	...
1930						
April 17	4.9	7.2	7.6	55	3.0	...
June 12	20.0	9.4	3.5	50	3.0	...
July 3	23.0	8.6	12.0	76	2.9	...
July 17	22.0	8.4	8.4	100	4.0	...
July 24	28.0	8.6	12.5	108	4.0	...
Aug. 2	27.0	8.4	3.2	110	3.0	...
Aug. 7	18.0	8.0	4.1	120	2.5	...
Aug. 18	18.0	8.0	5.6	140	2.5	...
Aug. 26	22.5	8.5	9.6	150	2.0	...
Sept. 6	16.0	8.4	7.0	130	2.0	...
Sept. 14	19.0	8.4	3.1	138	2.3	...
Sept. 19	16.0	8.4	4.0	125	2.7	...
Sept. 23	14.0	8.5	3.9	130	3.0	...
1931						
Aug. 14	28.0	9.0	9.7	136	0.0	...
1932						
Aug. 19	14.8	8.1	8.4	82	0.0	155
1933						
Aug. 18	....	8.5	7.8	84	0.0	120
Oct. 13	0.0–1.0	7.7	....	...	0.0	160
1934						
May 4	....	7.3	8.6	15	1.0	...
June 6	23.5	7.2	6.5	21	1.0	...
July 23	25.0	8.9	9.8	69	0.0	94
Aug. 17	22.8	8.2	6.5	62	0.0	120

Methyl orange. — Table I indicates the nature of the methyl orange alkalinity in parts per million of calcium carbonate. From these values and the information as to the phenolphthalein titrations, the calculations for normal carbonate, bicarbonate, and certain others can be made by well-known methods. These values show that in the quantities of carbonates Mud Lake water corresponds rather closely with that of Douglas Lake and certain other large lakes in the same region. This means that there is a much greater hardness in this water than would have been expected in a bog lake with such surroundings and type of bottom. In fact, this lake does not fall far short of being a "hard-water lake."

Hydrogen-ion Concentration

The striking thing about the hydrogen-ion concentration is that during the open season it is almost invariably on the alkaline side of the pH scale, in spite of the fact that the vegetational surroundings are such as to indicate an acid lake, and in spite of the fact that the water which saturates the floating mat is far on the acid side. It will be noticed from Table I that the pH values may be as high as 9.4, which is the most basic water, by far, in the whole surrounding region. The records in the table also show an unusual amount of change in the pH during certain seasons. Why such changes should occur is problematical. At rather infrequent intervals the water may become temporarily slightly acid. These variations do not appear to have any definite seasonal sequence. Detailed meteorological records are kept throughout the summer at the University of Michigan Biological Station, which is only about four miles from Mud Lake. Examinations of these records yield no evidence that pH variations are related to rainfall, wind disturbance, or any other meteorological circumstances. It is possible that the explanation may ultimately be found in the proximity of the false bottom to the surface of the water and that on some occasions there may be temporary inequalities of hydrogen-ion concentration in different areas over the lake owing to inequalities of chemical processes and release of chemical products from the false bottom. However, series of pH determinations were made in the form of transects across the lake and as nearly simultaneously as possible. All of these series made to date, except one, showed a uniformity of pH values. The exceptional series manifested

some lack of uniformity, although not of such an extent as to lend very strong support to the possible explanation mentioned above.

Since the pH of the water pocketed in the peripheral, floating mat is so strikingly different from that in the open lake, care was always taken to secure samples remote from shore. Some attention was given to the nature of the pH gradient where the open water met the floating mat. Almost invariably, during the summer season, the gradient was a very steep, short one, often involving a horizontal distance of not more than one meter, sometimes much less. Series of samples in the form of transects extending from the edge of the mat out into the open lake were made to secure information concerning the possible influence of the mat-impounded water upon the marginal lake water. In only one series was there evidence of a reduction of the basic reaction in the water within the ten-meter peripheral zone and it was not a very marked difference. This anomalous situation in which highly basic water and highly acid water maintain their original reactions unchanged to within a meter or less of each other is evidently due to the fact that the water in the mat is completely pocketed by the Sphagnum and other mat-forming plants. While the water of lake and mat are, in reality, continuous, mechanical mixing of the two waters is prevented, and diffusion of dissolved substances in immobilized water is exceedingly slow.

The paper by Goe, Erickson, and Woollett (1925) contains a set of pH records made by Dr. Minna E. Jewell on Mud Lake and its surrounding bog formations. Jewell and Brown (1929) give similar records. These records were made mostly in 1922 and supplement the records in Table I for that year.

Origin of Basic Reaction

Unfortunately, an adequate explanation of the origin of the basic reaction of the water of the lake, although surrounded by very extensive areas of acid-forming mats, is lacking. Jewell and Brown (1929) concluded that the acidity of the northern Michigan bog lakes which they studied "is due to organic acids which are produced in the lake margins and carried into the lake by water seeping through the acid-producing strata of the margin. The alkalinity of some bog lakes as compared with the acidity of others is explained as due to the entrance of water without traversing an acid-producing part of the margin." Since these authors based their conclusion concerning

alkaline bog lakes principally upon their studies of Mud Lake, it is pertinent at this point to evaluate their conclusion. It will be understood that the following discussion is based wholly upon the Mud Lake situation.

Gorham made a study (unpublished) of the origin of the reaction in both acid and alkaline bog lakes. His results pointed to conclusions different from those of Jewell and Brown. His observations and experiments seemed to show that (1) the source of the reaction is the same in all the bog lakes examined, both alkaline and acid; (2) the reaction arises, not directly from the marginal vegetation, living or dead, but from decomposing materials already within the lake itself; (3) the bottom débris is the only material having the same reaction as the lake water; and (4) the colloidal organic material in the lake water has the same reaction and is derived from these bottom deposits.

The writer also finds difficulties in accepting the Jewell and Brown explanation as applied to Mud Lake. The following features should be mentioned:

(1) The so-called inlet of Mud Lake at its extreme southeast end is essentially no inlet at all. During the summer the writer has never been able to find in it a detectable current. That it may represent the remnant of an old inlet is possible, but now it is little more than a narrow tongue of the lake extending back into the bog. Possibly it may function as a stream to a very slight degree after periods of unusually heavy rainfall, but even then the delivery of water must be relatively small and very slow. However, if it be granted, in spite of all appearances to the contrary, that this inlet does function in bringing drainage water into the lake, there still remains an obstacle. As has already been mentioned, the whole southeast end of the lake has been filled, for several years at least, with the false bottom which is at the surface of the water and which is now supporting a conspicuous vegetation of certain plants which can occupy such a water-saturated, finely divided mud. This great mass of emergent false bottom forms what is, in effect, a great mud dam across the mouth of the so-called inlet. Without doubt water entering from this so-called inlet might seep into and through the water-saturated, emergent mud barrier, but it would be very slow and far too ineffective to provide a source of alkaline water of sufficient quantity to maintain a lake as large as this one at its present

water levels and at its present pH values. Furthermore, there is no evidence that incoming surface drainage water would have anything like such high basic properties. A great many pH determinations have been made by the writer and his associates on surface drainage streams about Mud Lake, and thus far no such water has been found which approaches the high basic condition commonly maintained by Mud Lake water. It appears, from these facts, that something must be added to the water *after it gets into the lake basin.*

(2) Underground seepage has not been actually demonstrated, but since there are no other adequate sources of water supply for the lake it seems certainly to occur. Since various investigators have reported the fact that there is very little passage of water through peat, it appears that underground seepage, if present in any effective way, occurs at a level deeper than the peat deposits. However, it should be noted that, so far as it is known, the underground water of the surrounding region, which manifests itself in numerous springs, spring-fed streams, and lakes of other kinds obviously fed in part at least by subterranean water, although alkaline in reaction, never shows a basic reaction of more than about pH 8.0 and often less. It would seem, then, that an additional contribution of basic-reaction-forming materials must be added *after the water enters the lake basin.*

(3) Gorham performed ultrafiltration tests with various bog-lake waters and demonstrated (*a*) that, when passed through an ultrafilter, such waters lost their basic or acid reaction and became almost neutral; (*b*) that, when the materials retained by the filter were added to neutral distilled water, a reaction was caused which virtually reproduced the pH of the original lake water and of the bottom sediments; and (*c*) that, when the materials retained by the ultrafilter were dried and then added to carefully distilled water, the resulting reaction was approximately that of the original water; and that incineration of this dried residue proved it to be organic in nature. From these experiments and others Gorham concluded that the reaction of bog-lake waters is due to organic substances in the water in colloidal form. Recently this conclusion has been confirmed by Cowles and Brambel (1934). In the past the writer and his associates have made numerous examinations of the underground water of the general region in which Mud Lake is located by sampling from springs, spring-fed streams, and driven wells of various depths, and have found such waters always very clear, very low in color, very low

in organic colloidal matters, and with a reaction not very far from neutrality. It thus seems reasonably certain that, whatever may be the inflowage of underground water into Mud Lake, this water arrives at the lake basin without those organic colloidal matters which give the open lake water its unique reaction. Here is still a third argument for holding that the reaction-giving substances are acquired as the water passes through the bottom sediments.

Since it appears, then, that the basic reaction is dependent upon materials already in the lake, the question arises, Whence came these substances? No positive answer can be given at this time, but the indications are as follows. Bog lakes fill, commonly, by one or both of two sets of processes, namely, encroachment of the marginal mat and deposits in the bottom from the partly decayed remains of aquatic vegetation. Owing to the position and character of the false bottom Mud Lake now has no submerged, higher aquatic vegetation, except a very narrow marginal zone along the southwestern shore, nor has it had any for a very long time in the past. However, from what is now known about the morphology of the original basin and about the composition of the bottom deposits, it seems certain that in its early history Mud Lake must have supported a submerged vegetation, possibly an abundant one. After the great marl deposit had been laid down, an enormous mass of peaty materials was formed in the lake. This can only mean that at least the sources of these materials were reasonably ample. Likewise, in the light of the physiographic make-up of Mud Lake surroundings, these sources must have been (1) the marginal vegetation, (2) the vegetation growing in the basin, and (3) minor additions due to indrainage and to wind-blown materials. During the evolution of the lake the higher aquatic vegetation within it almost disappeared, but its resulting peat remains. The marginal mat, which now surrounds the lake, gives to its own impounded water an acid reaction. This mat presents three different sections: (1) A narrow section extends about the northwest end of the lake and for some distance down each side and is composed primarily of Carex; another portion of the same kind of mat occurs on the south shore and at the southeast end. These two portions are separated by a very short strip of shore on which bog trees (Picea and Thuja) come almost to the water's edge, and another small area of shore on which mixed trees (mostly aspens) likewise extend close to the water. (2) A wide Chamaedaphne-Sphagnum

mat occupies the remainder of the lake margin. There is reason for believing that the narrow Carex mat is of fairly recent origin; that the lake probably existed for a very long time without a mat along about three fourths of its shore; and that the succeeding conditions leading to peat formation about most of the shore were very different from those which now prevail. Gorham claimed that the "major portion of the bottom material [in Mud Lake] is of sedge, bog forest, and sedimentary origin," materials which are said to produce peats with basic reaction. He also recognized the possibility that the restricted indrainage may have brought into the lake some mineral salts which augmented the basic condition. Various investigators of the chemistry of peat claim that the chemical composition of any layer in a peat profile depends (1) upon the nature and the chemical composition of the vegetation from which the layer originated, and (2) upon the conditions under which its decomposition has occurred; and that this chemical composition of the peat is independent of the region, the topography, and the history of the bog. In the light of the circumstances described above and the results of work done on other types of bog lakes to be described in later papers, the writer is disposed to favor Gorham's interpretation, namely, that a part of the now-existing enormous mass of bottom peat in Mud Lake came, in times past, from marginal materials, different from those now developing, which produced basic conditions, and that the resulting peats continue to give off basic substances to the incoming water in quantities sufficient not only to maintain the present high basic reaction but also to offset any possible inseepage of acid water from the now-existing peripheral mats. The writer would add one modifying postulation to Gorham's theory, namely, that possibly preëxisting crops of submerged vegetation may have contributed substantially to the basic-producing bottom peat. It is known that, when the typical submerged vegetations of northern Michigan lakes undergo partial decay under conditions which lead to peat formation, the peaty materials which they produce seem to be of the basic sort.

It seems necessary, in the light of all information available at this time, to conclude that (1) the conspicuous basic reaction of Mud Lake water is due to the peat deposits already within the lake basin; (2) these immense deposits must have come originally from contributions from the onshore bog forests, the marginal (mat ?)

vegetation, the preëxisting vegetation within the lake itself, and minor quantities from outside sources; and (3) such acid-producing substances as may make their way into the lake from the Chamaedaphne-Sphagnum and the Carex mats have as yet no detectable effect.

Iron

The writer has made no determinations of iron in Mud Lake waters. Gorham made quantitative analyses of both ferrous and ferric iron in 1930. His ten determinations, distributed over the open season from May 10 to September 22, showed quantities so very low (0.25–1.5 p.p.m. total iron) that it scarcely seems likely that it can have a limiting influence upon the plankton owing to a toxic action, as has been claimed for some European bog waters.

Conductivity

Table I includes a representative set of conductivity records from Mud Lake water. It is not possible at this time to explain the variations manifested. When compared with conductivity tests on other bog lakes in the Douglas Lake region, the Mud Lake values are about intermediate between the extremes found.

BIOLOGICAL FEATURES

Biologically a true bog lake differs in many respects from other types of lakes, these differences relating to both their plant and their animal populations. This statement is outstandingly true of Mud Lake.

Vegetation

Fortunately the principal vegetation features of this lake, as well as those of the surrounding bog margins, have been well treated by Goe, Erickson, and Woollett (1925) and need not be discussed here. Also, certain facts have been presented by Jewell and Brown (1929). Interested readers should refer to these papers, particularly the former, for detailed information.

Plankton

In this investigation special attention has been given to the plankton. Data upon which this section is based were mostly ac-

cumulated during the summers of 1932, 1933, and 1934. A few additional records have been made at seasons other than midsummer, and some scattering records are for summers earlier than those mentioned above. Almost no winter data are available, since this lake is inaccessible at that time of year.

Qualitative Plankton Records

Owing to the nature of the overgrowing marginal mat, the proximity of the false bottom to the surface, and certain other peculiar circumstances, it was necessary to try to distinguish between the *true plankters* and those other microörganisms which may be taken in plankton collections, such as those originating from the bottom. To avoid the inclusion of marginal forms, collections were always made well out in the open water. They were also made in such a way as to cause as little disturbance in the water as possible, since flocculent materials from the false bottom are notorious for the ease with which they come up into flotation in the overlying water. These flocculent materials, when present, not only cause difficulty in the collection and the examination of samples, but also may be the carriers of microörganisms of certain kinds which are not true plankters. In spite of these precautions it is likely that some mixture of true plankters, marginal forms, and bottom forms was unavoidable. Since the microörganisms of the false bottoms of these bog lakes have never been studied, it is not possible, at the present time, to recognize those organisms whenever they occur in plankton collections. Therefore, it is admitted at the outset that the list of organisms here designated as plankters may later be found to contain some marginal and bottom forms.

The records here included are mostly from collections made with a standard, number 20 silk plankton net. A few collections have been made by means of the electric plankton centrifuge, but much less attention has been given to the minute nannoplankton. Not only will much more work be required to make known the character of the nannoplankton, but the difficulties and the incompleteness of taxonomic knowledge of these nannoplankton organisms make a qualitative study almost impracticable at the present time.

LIST OF PLANKTERS FROM MUD LAKE

PHYTOPLANKTON[1]

MYXOPHYCEAE

Chroococcales

Chroococcaceae

Aphanothece microscopica Näg. (?)
Aphanothece nidulans Richter
Aphanothece stagnina (Sprenger) A. Braun
Chroococcus giganteus W. West
Chroococcus limneticus Lemm.
Chroococcus turgidus (Kütz.) Näg.
Coelosphaerium dubium Grunow
Coelosphaerium naegelianum Unger (?)
Merismopedia elegans A. Braun
Microcystis aeruginosa Kütz.
Microcystis flos-aqueae (Wittr.) Kirchner
Microcystis ichthyoblade Kütz.
Microcystis marginata (Menegh.) Kütz.

Hormogoneales

Oscillatoriaceae

Lyngbya Birgei G. M. Smith
Oscillatoria sp.
Spirulina major Kütz.

Stigonemataceae

Stigonema hormoidea (Kütz.) Bornet and Flah. (?)

HETEROKONTAE

Heterococcales

Botryococcaceae

Botryococcus braunii Kütz.
Botryococcus sudeticus Lemm.

CHRYSOPHYCEAE

Chrysomonadales

Ochromonadaceae

Dinobryon sp.

BACILLARIEAE

Pennales

Tabellariaceae

Tabellaria fenestrata Kütz.
Tabellaria flocculosa (Roth) Kütz.

Fragilariaceae

Fragilaria sp.
Fragilaria crotonensis Kitton
Synedra sp.

Naviculaceae

Navicula sp.

Gomphonemataceae

Gomphonema sp.

Cymbellaceae

Amphora sp.

CHLOROPHYCEAE

Tetrasporales

Tetrasporaceae

Tetraspora sp.
Tetraspora gelatinosa (Vauch.) Desvaux

Oedogoniales

Oedogoniaceae

Bulbochaete sp.
Oedogonium sp.

Chlorococcales

Hydrodictyaceae

Pediastrum areneosum Raciborski
Pediastrum duplex Meyen.
Sorastrum bidentatum Reinsch.

Oocystaceae

Chlorella vulgaris Beyerinck
Dictyosphaerium pulchellum Wood
Dimorphococcus lunatus A. Braun

[1] Classification of the Algae according to Smith (1933).

Scenedesmaceae

Scenedesmus sp.
Scenedesmus bijuga (Turp.) Lagerh.
Scenedesmus quadricauda (Turp.) Bréb.

Zygnematales

Zygnemataceae

Mougeotia sp.
Spirogyra sp.

Desmidaceae

Closterium parvulum Näg.
Cosmarium Botrytis Menegh.
Gymnozyga moniliformis Ehrenb.
Hyalotheca dissiliens (Sm.) Bréb.
Micrasterias crux-melitensis (Ehrenb.) Hass.
Micrasterias rotata (Grev.) Ralfs.
Staurastrum sp.
Staurastrum branchiatum Ralfs.
Staurastrum gracile Ralfs.
Staurastrum pachyrhynchum Nordst.

DINOPHYCEAE

Dinophyceae

Ceratium hirundinella O. F. Müller

EUGLENOPHYCEAE

Euglenales

Euglenaceae

Euglena sp.

ZOOPLANKTON

PROTOZOA

Arcella vulgaris Ehrenb.
Centropyxis aculeata Stein
Coleps octospinus Noland
Difflugia pyriformis Perty
Epistylis sp.
Stentor sp.
Urceolus cyclostomus (Stein)
Vorticella sp.

ROTIFERA [2]

Collotheca mutabilis (Hudson)
Colurella deflexa (Ehrenb.)
Conochilus unicornis Rousselet
Keratella sp.
Keratella cochlearis (Gosse)
Lecane luna (O. F. Müller)
Lepadella acuminata (Ehrenb.)
Lepadella triptera Ehrenb.
Monostyla sp.
Monostyla crenata Harring
Monostyla lunaris (Ehrenb.)
Mytilina sp.
Mytilina mucronata spinigera (Ehrenb.)
Mytilina ventralis brevispina (Ehrenb.)
Notholca longispina (Kellicott)
Notommata sp.
Philodina roseola Ehrenb.
Polyarthra trigla Ehrenb.
Rotaria tardigrada (Ehrenb.)
Trichocera sp.
Trichocera cylindrica (Imhof)
Trichocera lata (Jennings)
Trichotria tetractis (Ehrenb.)

CLADOCERA

Alonella sp.
Bosmina longirostris (O. F. Müller)
Bosmina longispina Leydig
Ceriodaphnia sp.
Chydorus sphaericus (O. F. Müller)
Diaphanosoma brachyurum leuchtenbergianum Fischer

COPEPODA

Cyclops sp.
Diaptomus sp.
Diaptomus leptopus Forbes

INSECTA

Corethra sp.

GASTROTRICHA

Chaetonotus similis Zelinka

[2] Nomenclature according to Harring (1913).

An analysis of this list of plankters yields the following features: (*a*) a larger number of species than statements in previous literature would lead one to expect in bog lakes; (*b*) many genera as compared with the number of species; (*c*) a preponderance of phytoplankters; (*d*) the very small number of diatoms and copepods; and (*e*) the generous and diversified representation of rotifers.

Quantitative Records

Owing to the fact that Gorham made an extensive series of quantitative studies, by the statistical method, of the net plankton of Mud Lake during the summer of 1930, the writer confined his attention to other features of the work. The following table (Table II) contains data selected from more detailed work of Gorham and will suffice to show in a general way the character of the plankton production.

TABLE II

QUANTITATIVE COUNTS OF NET PLANKTON COLLECTED FROM MUD LAKE, 1930

All values represent the number of organisms per liter of lake water. All data by W. C. Gorham (*unpublished*).

Date	Total phyto-plankton	Total zoo-plankton	Total of all plankton
June 18	120	430	550
July 3	220	710	930
July 17	170	130	300
Aug. 2	250	60	310
Aug. 7	190	40	230
Aug. 18	70	40	130
Aug. 26	380	10	390
Sept. 6	110	30	140
Sept. 19	30	10	40
Sept. 23	480	20	500

Certain features of plankton production appear in this table: (*a*) The plankton production as a whole is very low; (*b*) There is a falling-off of production as the summer progresses, with an apparent increase in late September; (*c*) In early summer the zooplankton

exceeds the phytoplankton, but during the remainder of the summer and in the early autumn the phytoplankton predominates.

Gorham found that among the phytoplankton, *Microcystis aeruginosa* was numerically dominant at all dates when counts were made. Among the zooplankton the rotifer population varied greatly on different dates, and *Keratella cochlearis* on one occasion (July 3) rose to 650 per liter and composed approximately two thirds of the total net plankton, although during the remainder of the summer it occurred in only very small numbers.

MACRO-FAUNAL FEATURES

Bottom Fauna

This type of lake is unique in virtually lacking a true bottom fauna. The nature of the false bottom is such as to preclude any bottom dwellers which are so commonly found in other kinds of lakes. With the possible exception of certain microscopic and semimicroscopic forms which may occur in the uppermost stratum of the false bottom, there is no true benthos. Likewise, owing to the peculiar nature of the overgrowing marginal bog mat, this absence of bottom fauna extends, in most places, completely to the periphery of the open water. This lake is, then, a striking instance of a body of water practically devoid of one of the most influential features in biological productivity, namely, the bottom fauna. In this lake productivity depends almost wholly upon the open water, the limited marginal relations, and possibly to some extent upon those microscopic and semimicroscopic animals and algae which can inhabit the surface of tenuous false bottom.

Marginal Fauna

The edge of the floating bog mat offers support and retreat for certain animals. The same is true of the extremely narrow vegetation zone on part of the south shore, of the partly submerged trees along shore, and of the few stray islands of water lilies which now are getting established in some portions of the open lake. Jewell and Brown (1929) made a rather extensive survey of the fauna of this lake and listed a considerable number of animals, most of which are marginal forms. Subsequent examinations by the writer agree closely with the findings of Jewell and Brown.

Open-Water Fauna

In addition to the zooplankton which has already been discussed, the open-water fauna consists almost wholly of certain fishes. Jewell and Brown (1929) record five species from this lake, namely, red-bellied dace, *Chrosomus erythrogaster;* bronze minnow, *Pfrille neogaea;* blackhead minnow, *Pimephales promelas;* mud minnow, *Umbra limi;* and the brook stickleback, *Eucalia inconstans.* Of these, only the first three were taken in the open water, the last two occurring only in the inlet and the outlet. Subsequent examinations have made no additions to this list. The red-bellied dace was by far the most abundant of the fishes.

Productivity

Leeches, sponges, and a few other animals seem to be regularly quite abundant, but in general the production of the macroscopic animals is very low. Apparently, most species occurring in this lake manage to do little more than hold their own. The absence of a true bottom fauna and the exceedingly scant aquatic vegetation are in themselves sufficient to reduce animal population to a low state.

Dynamics of Lake

This lake has now reached the stage in which bottom encroachment is outrunning the marginal encroachment, and it seems certain that the remaining part of its history will be that of bottom capture. Some further encroachment of the mat will, of course, occur, but its part will probably be insignificant. In fact, as already mentioned, the bottom has reached the top over a considerable area at the southeast end of the lake and shows an increasing solidification and an overgrowth of certain plants. So rapidly does this bottom capture seem to be occurring at the southeast end that the next decade will probably bring about a still further substantial loss of the open water.

SUMMARY

1. Mud Lake, Cheboygan County, Michigan, is a type of bog lake which is unique in being surrounded by a typical overgrowing, acid-forming bog mat, but the water of the open lake is unusually basic.

2. Much filling of the basin has occurred in the past, and the false bottom is now very near the surface.

3. The peculiar conditions of temperature, color, turbidity, dissolved gases, alkalinity, hydrogen-ion concentration, iron content, and electrolytes are discussed in some detail.

4. Evidence is presented which indicates that (*a*) the conspicuous basic reaction of Mud Lake water is due to the deposits already within the lake basin; (*b*) these immense deposits must have come originally from contributions from the onshore bog forests, the marginal vegetation, the preëxisting vegetation within the lake itself, and minor quantities from outside sources; and (*c*) such acid-forming substances as may make their way into the lake from the present acid mat seem to have no significant effect.

5. Special attention has been given to the plankton, and a list of about one hundred species is included. This list shows (*a*) a larger number of species than previous literature indicates for bog lakes; (*b*) many genera as compared with the number of species; (*c*) a preponderance of phytoplankton; (*d*) the very small number of diatoms and copepods; and (*e*) the generous and diversified representation of rotifers.

6. Quantitative measurements indicate that (*a*) The plankton production is as a whole very low; (*b*) There is a falling-off of production as the summer progresses, with an apparent increase in late September; and (*c*) In early summer the zooplankton exceeds the phytoplankton, but during the remainder of the summer and in the early autumn the phytoplankton predominates.

7. This lake is unique in the almost total absence of a bottom fauna.

8. The marginal fauna is a very limited one and is restricted to an exceedingly narrow zone.

9. With the exception of certain ubiquitous aquatic insects, the open-water fauna consists almost exclusively of three species of fish.

10. Biological productivity, for the lake as a whole, is very restricted.

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LITERATURE CITED

Auer, V. 1933. Peat Bogs of Southeastern Canada. Handbuch der Moorkunde, 7: 141–223.

Cowles, R. P., and Brambel, C. 1934. The Acidity of the Water of a Sphagnum Swamp. Program for the Thirty-second Annual Meeting of the American Society of Zoologists, Abstracts of Papers. Anat. Record, Vol. 60, Suppl., p. 97.

Dachnowski-Stokes, A. P. 1933. Peat Deposits in U. S. A. Their Characteristic Profiles and Classification. Handbuch der Moorkunde, 7: 1–140.

Davis, C. A. 1907. Peat, Essays on Its Origin, Uses and Distribution in Michigan. Report of the State Board of Geological Survey of Michigan for the Year 1906, pp. 95–395.

Goe, L., Erickson, E., and Woollett, E. 1925. An Ecological Study of Mud Lake Bog, Cheboygan County, Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 4, Part I (1924): 297–310.

Gorham, W. C. A Limnological Study of Certain Bog Lakes, with Special Reference to the Macroplankton. (*Unpublished.*)

Harring, H. K. 1913. Synopsis of the Rotatoria. U. S. Nat. Mus., Bull. 81: 1–226.

Jewell, M. E., and Brown, H. W. 1929. Studies on Northern Michigan Bog Lakes. Ecology, 10: 427–475.

Smith, G. M. 1933. The Fresh-Water Algae of the United States. New York. 716 pages.

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